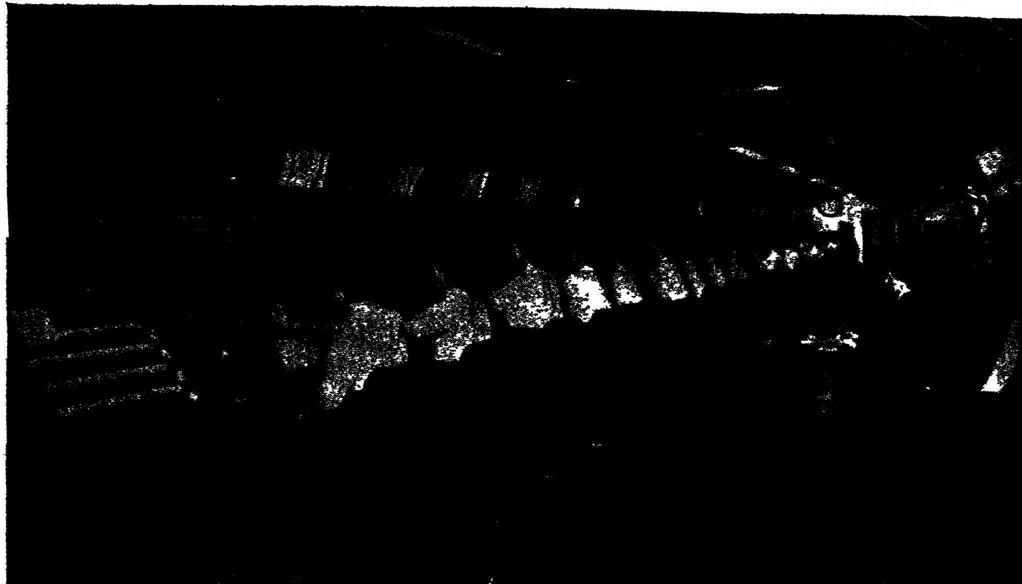

A MODERN TELEPRINTER SWITCHBOARD INSTALLATION. (*By courtesy of the Signal Division, Admiralty.*

MODERN TELEGRAPH SYSTEMS AND EQUIPMENT

COVERING VOICE FREQUENCY, TELEX, SUB-AUDIO AND VARIOPLEX SYSTEMS, AND ALL TYPES OF MODERN APPARATUS INCLUDING THE TELEPRINTER, TELETYPEWRITER AND CREED AUTOMATIC 5–UNIT AND MORSE EQUIPMENT

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PREFACE

THERE have been many developments in Telegraph technique during the last decade, such as the introduction of the teleprinter through switching using telegraph switchboards; teleprinter transmission and reception over H.F. radio links, using multi-channel voice frequency telegraph systems and five-unit automatic apparatus. The Western Union Varioplex and the Siemens and Halske Hell Teleprinter systems, too, have been developed in recent years.

This book has been written with the object of bringing these developments and current practice to the notice of telecommunication engineers, traffic officers and students of electricity and radio-communication.

The author is indebted to Messrs. Creed & Co., Ltd., for the use of blocks and material relating to the teleprinter and associated automatic apparatus, and the high speed morse system.

Acknowledgment is also made to Mr. Barkwith, Chief Engineer, Western Union Telegraph Company, for his assistance in connection with Varioplex Telegraphy which is dealt with in Chapter VI, and to Mr. Hughes of the Engineer-in-Chief's Department, G.P.O., Telegraph Branch, for the description of the Hell Teleprinter System.

At the end of the book will be found a list of terms and definitions, many of which are new; these are included to assist the reader should he encounter unfamiliar terms when reading this publication.

W. T. PERKINS.

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MODERN TELEGRAPH SYSTEMS AND EQUIPMENT

CHAPTER I

MULTI-CHANNEL VOICE FREQUENCY TELEGRAPHY

ANY system of conveying messages by signals over a distance is referred to as a *telegraph system.* Formerly the term applied to semaphore and other visual systems, but now it almost exclusively refers to electrical systems. The four most important developments in telegraph communications in Great Britain in recent years have been:

(1) The extensive use of teleprinters as the transmitting and receiving apparatus.

(2) The introduction of multi-channel voice frequency telegraph systems which enable a maximum of eighteen telegraph circuits to be worked over a four-wire telephone trunk circuit or over a radio link.

(3) The installation of a large number of teleprinter switchboards throughout Great Britain enabling long distance teleprinter communications to be established in a manner similar to the telephone switching system.

(4) The perfection of morse and five unit code automatic equipment whereby messages can be transmitted and received at steady high

speeds so as to make the most economical use of the expensive transmission line circuits.

Teleprinters and morse equipment can be worked over voice frequency telegraph systems since both forms of communication transmit direct current signals which are converted into alternating currents within the frequency range of speech for transmission over the four-wire trunk circuit. It will be apparent, therefore, from (2) above, that in these days of acute shortage of long-distance trunk telephone circuits, a channelling system whereby 18 telegraph circuits can be obtained from one telephone trunk circuit, has proved of great value.

The Multi-Channel Voice Frequency Telegraph System

A multi-channel voice frequency telegraph system is the name given to a communication system whereby a number of telegraph circuits are provided from one long-distance telephone trunk circuit or radio link. Fig. 1 is a block schematic of the arrangement. There are at present 4, 8, 12 and 18 channel, voice frequency telegraph systems working in this country. At the voice frequency terminal stations a number of different carrier frequencies (all within the voice frequency range) are generated and transmitted through the telephone trunk circuit.

The carrier frequencies generated by voice frequency terminal Station **A** are transmitted over the upper pair of wires, known as the *Go* pair and those generated by Station **B** over the lower pair of wires, known as the *return* pair of the circuit. Each telegraph office instrument connected to the system is allocated a given carrier frequency, or channel frequency, and the dc. signals emanating from this instrument, i.e. teleprinter or morse

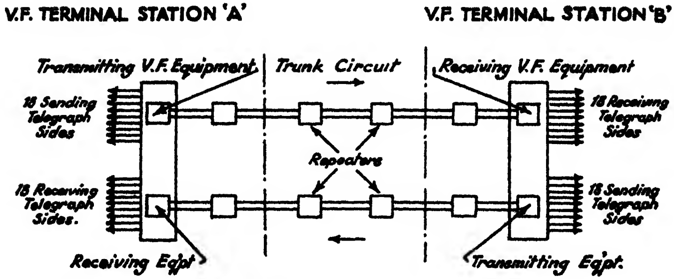


FIG. 1.—A FOUR-WIRE TRUNK CIRCUIT MODIFIED FOR AN 18 CHANNEL V.F. SYSTEM.

key, are made to modulate the associated carrier wave. The telegraph office may be situated near the voice frequency terminal station or as far away as twenty miles, connection between the two being by means of a two-wire circuit.

To build up a multi-channel voice frequency system step by step, it is necessary to understand the function of the fundamental parts, the two most important of which are:

The telephone trunk circuit.

The two multi-channel voice frequency terminal equipments (one at each end of the trunk circuit).

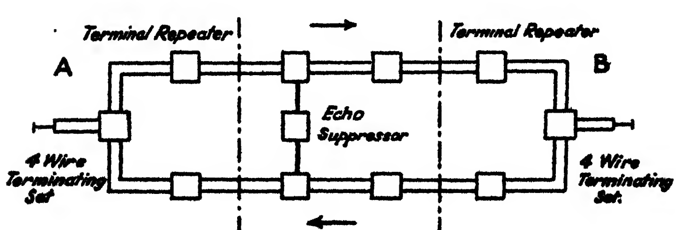


FIG. 2.—A FOUR-WIRE LONG DISTANCE TELEPHONE TRUNK CIRCUIT.

The Trunk Circuit.

A long-distance telephone trunk circuit consists of four wires with repeaters, echo suppressor and four-wire terminating sets as shown in Fig. 2. When the trunk circuit is used to carry a voice frequency telegraph system the upper pair of conductors are used for telegraph transmission in one direction and the lower pair of conductors for transmission in the reverse direction. The echo suppressor is dispensed with and the four-wire terminating sets replaced by V.F. terminal equipment. Amplifier repeaters are inserted at intervals (of say fifty miles) along the circuit, they receive the attenuated signals and retransmit them along the next section of the circuit with increased power. By this means the telegraph signals are received at the distant end with a power equal to that originally transmitted. The trunk circuit carries the complex wave made up of the different modulated carrier frequencies.

The Multi-Channel Voice Frequency Terminal—Equipment.

The multi-channel voice frequency terminal equipment will be considered in two parts:

The Transmitting equipment.
The Receiving equipment.

The Transmitting Equipment.

This consists of the apparatus for generating the carrier frequencies, i.e. either valve oscillators or an inductor type alternator known as a voice frequency generator, together with the send relays, filters, and the send line transformer (see Fig. 3). Valve oscillators are used at the out-stations on 4 and 8 channel V.F. systems and a

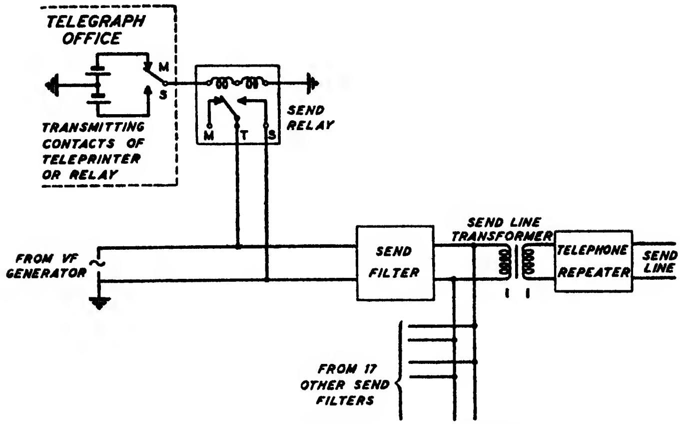


FIG. 3.—THE TRANSMITTING EQUIPMENT.

V.F. generator on 12 and 18 channel V.F. systems, and 4 and 8 channel in-station equipments. A simple valve oscillator circuit as used with a 4 channel V.F. system is shown in Fig. 4, a separate valve oscillator, and different frequencies being used foı each channel of the system.

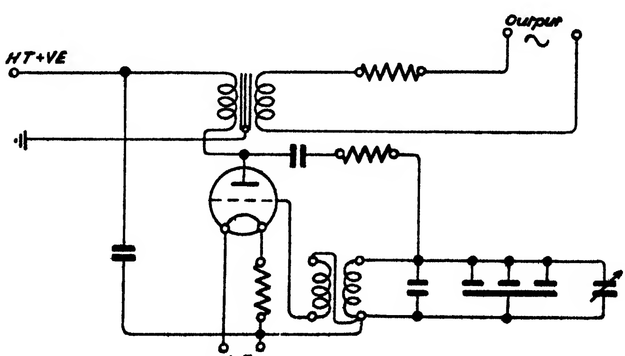


FIG. 4.—A SIMPLE VALVE OSCILLATOR CIRCUIT.

The Motor-Driven Voice Frequency Generator.

The generator is an inductor alternator designed to produce current at eighteen different frequencies.

Fig. 5 shows the principle of the inductor alternator. The armature winding is wound on the projections of the stator, while for clearness the field winding is shown on the legs of the field magnet system. The rotor is simply a soft iron cylinder with projections whose width corresponds to the pole pitch of the stator.

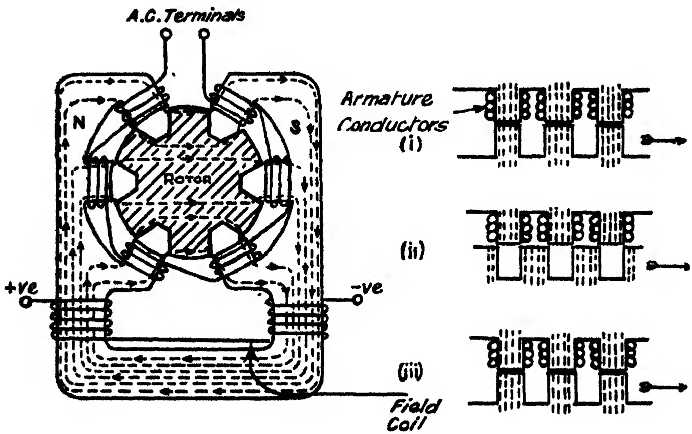


FIG. 5.—ILLUSTRATING THE PRINCIPLE OF THE INDUCTOR ALTERNATOR.

Fig. 5 also illustrates the action. When a stator tooth is opposite a rotor tooth Fig. 5 (i) and (iii) the magnetic flux is a maximum since the reluctance of the path formed by the iron teeth is small. The reluctance increases and the magnetic flux consequently falls when a space in the rotor is opposite a pole of the stator Fig. 5 (ii) since the flux is compelled to traverse the air path. Thus the flux is formed into *tufts* each time a rotor pole

is opposite a stator pole (i) and (iii). When the poles are in the midway position (ii) the flux is evenly distributed across the air gap. Therefore, considering any one stator pole, the magnetic flux is continually varying, being spread out and gathered in again. E.M.F.s are, therefore, induced in alternate directions in the coils wound on the pole pieces, each time a rotor tooth passes a stator pole. The frequency is equal to the speed of rotation in revolutions per second multiplied by the number of rotor teeth. The rotor of the machine used for multi-channel working has eighteen laminated soft iron discs, each slotted differently so as to produce the eighteen frequencies required. These are mounted on the same shaft as the armature of the driving motor, so that the machine consists of eighteen separate inductor alternators and a driving motor all in one unit. The eighteen separate stator windings have a common field exciting current supplied from a 24-volt battery and controlled by a rheostat. The make-up of the machine may be seen from Fig. 6, which shows the generator dismantled, whilst Fig. 31 page 36, shows its position on an 18 channel V.F. bay. The frequencies generated are:
420, 540, 660, 780, 900, 1,020, 1,140, 1,260, 1;380, 1,500, 1,620, 1740, 1,860, 1,980, 2,100, 2,220, 2,340, and 2,460, c.p.s.

One such generator is capable of supplying the needs of ten eighteen-channel voice frequency systems.

Control or Modulation of the Generated Carrier Frequencies.

The transmission of the carrier current is controlled by means of a send relay otherwise known as a telegraph modulator.

The V.F. Send Relay.

The V.F. send relay is of the polarised type, having a contact which when operated short-circuits the V.F. channel. This type of relay has now been superseded by a telegraph modulator or static relay. The main

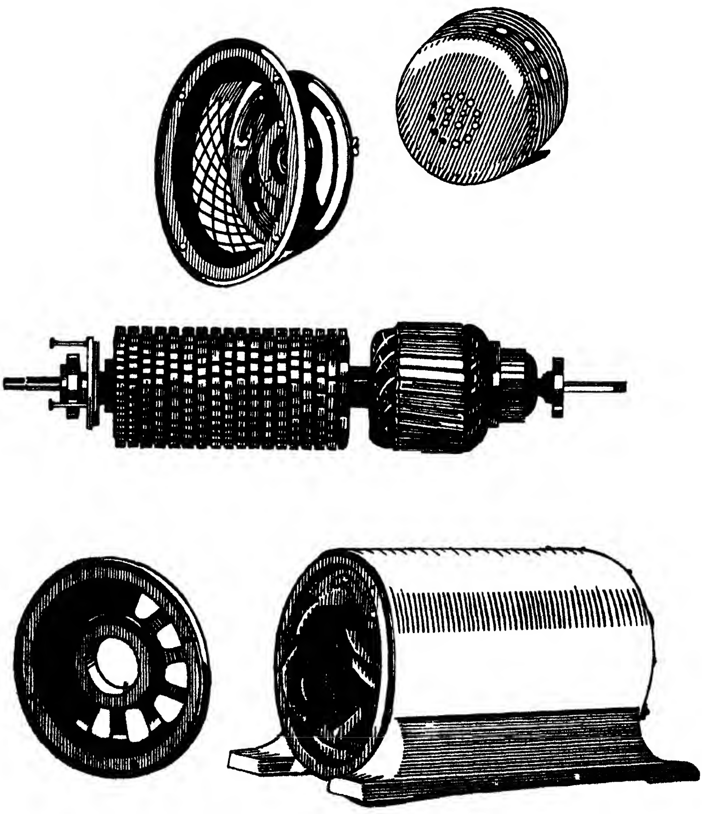


FIG. 6.—THE 18 FREQUENCY GENERATOR (DISMANTLED).

reason for leaving the polarised relay with its contact in these diagrams is that the action is simple to follow from the reader's point of view. The static relay performs exactly the same functions as the polarised send relay, and possesses the advantage that it has no moving parts and therefore requires no adjustment. Moreover, the static relay has no defect comparable with the bounce or chatter of an ordinary relay contact.

The V.F. Static Relay or Telegraph Modulator.

Fig. 7 shows the circuit arrangement of the V.F. *send*, or static relay. It is made up of eight metal rectifiers connected up to form two bridges S and M. The points P, P_1, of the bridge S are connected via condenser C to the secondary of a transformer. The primary of the transformer is connected permanently across the V.F. line circuit. Its action is dependent upon the fact that the impedance of a copper oxide rectifier to a small

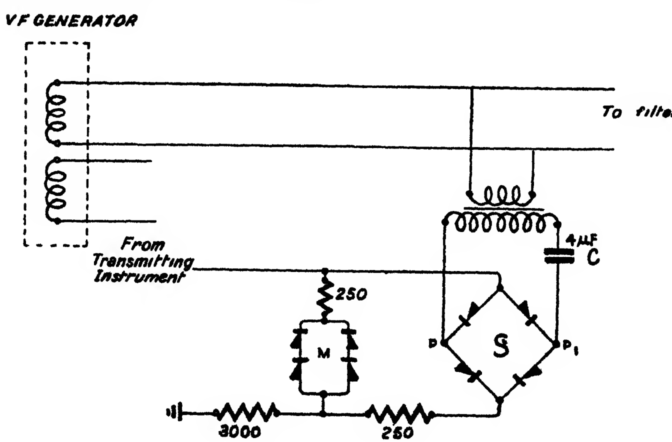


FIG. 7.—THE STATIC RELAY CIRCUIT.

alternating current may be varied by the value and polarity of a small steady applied voltage. Negative marking currents from the teleprinter will pass through the network *M* but have no path through *S*; similarly positive spacing currents may pass through the network *S* but not through *M*.

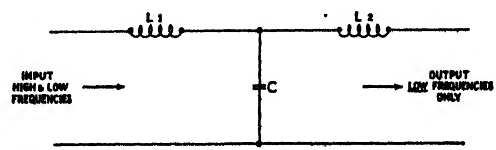
If a *marking signal* is applied to network *M*, the potential difference developed across the *M* network and its 250 ohm series resistance acts as a negative bias applied across the *S* bridge. This bias is sufficient to prevent the passage of the alternating currents (induced from the V.F. circuit via the primary of the transformer) passing between points *P* and P_1. In effect the transformer behaves as if the secondary were an open circuit. With this condition the power of the transmitted V.F. carrier is at a maximum and the carrier passes to the filter.

When a spacing signal from the teleprinter is applied to the *S* network the rectifiers are biased in such a direction as to offer a minimum impedance to the alternating current in the secondary of the transformer; this is equivalent to a short circuit across the secondary. Under this condition the secondary winding absorbs maximum power from the primary, so that the V.F. carrier is attenuated to such an extent that it is prevented from reaching the input of the *send* filter. This condition is equivalent to a short circuit across the V.F. supply circuit. Thus carrier current is transmitted to the line and receiving V.F. terminal apparatus for a mark signal and suppressed for a space signal. In the rest condition, that is when the telegraph instrument is idle, the channel is continuously marking and carrier current transmitted.

Filters.

A filter consists of a network of inductance coils and condensers so arranged that they will offer little or no impedance to alternating currents within a given frequency range and a very high impedance to alternating currents outside that range. The filters used in telegraphy are of three main types, namely the low pass filter, the high pass filter, and the band pass filter. These are illustrated diagrammatically together with their attenuation characteristics in Figs. 8 to 13. The filters used in multi-channel voice frequency telegraph systems are all of the band-pass type, but the action of the low pass and high pass filters is also described as the band pass filter is a combination of these two types.

FIG. 8.
LOW PASS
FILTER.



LOW PASS FILTERS. When a mixture of high and low frequencies are applied to the filter circuit in Fig. 8, the higher frequencies will be passed mainly via the condenser *C*. On the other hand the lower frequencies will pass quite readily via the inductances L_1 and L_2.

By choosing suitable values for L_1, L_2 and C, currents at all frequencies higher than a predetermined value will *not* pass through the filter whilst currents at frequencies below this value down to zero frequency will pass quite readily. Hence this type of filter is known as a *low pass filter*.

A typical low pass filter characteristic showing the attenuation for increasing frequencies is given in Fig. 9.

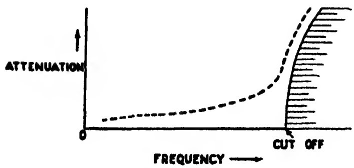
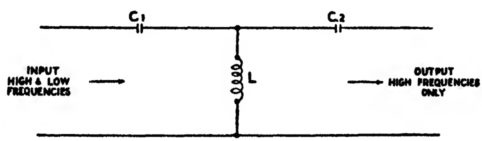


FIG. 9.—ATTENUATION CHARACTERISTICS OF A LOW PASS FILTER.

The shaded portion indicates the non-transmitted range in the case of resistanceless components whilst the dotted curve shows the more practical case where resistance is present. This has a flattening effect so that the cut-off frequency is not clearly defined.

FIG. 10. THE HIGH PASS FILTER.



HIGH PASS FILTERS. The circuit of a high pass filter is shown in Fig. 10. The higher frequencies will be passed readily via C_1 and C_2 whilst the lower frequencies will be passed mainly via L. Suitable values of C_1, C_2 and L ensure that only frequencies higher than a predetermined value will pass through the filter.

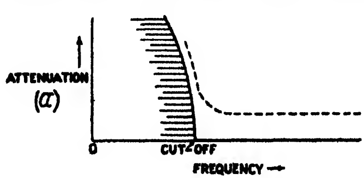


FIG. 11.—THE ATTENUATION CHARACTERISTICS OF A HIGH PASS FILTER.

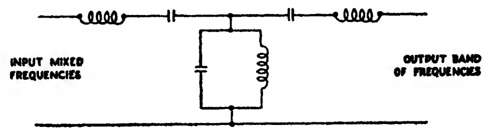
A typical high pass filter characteristic is shown in Fig. 11. The dotted curve again shows the effect of resistance in the components.

BAND PASS FILTERS. As its name implies a band pass

filter (Fig. 12) will pass a band of frequencies between lower and upper limits, determined by the values of the components.

It is a combination of a low and a high pass filter and cuts off all frequencies above and below two given frequencies, whilst allowing those between to pass. A typical characteristic is shown in Fig. 13.

FIG. 12.
THE BAND PASS FILTER.



Any of these circuit arrangements allow undesirable frequencies to pass to some extent although they will be more or less attenuated. If two or more similar filters are connected in series then the arrangement will be more efficient for barring those frequencies which are not required.

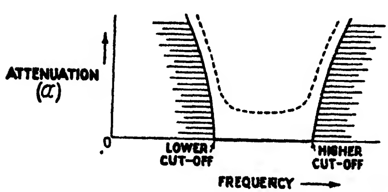


FIG. 13.
THE ATTENUATION CHARACTERISTICS OF A BAND PASS FILTER.

THE SEND FILTER. The sending filters are designed to transmit as wide a range in the neighbourhood of the carrier frequencies as is necessary to secure the desired speed of transmission and at the same time exclude extraneous currents.

The purpose of the send filters is twofold. (1) They prevent currents of undesirable frequency from being

transmitted to the line, and (2) they offer a high impedance to the outgoing currents of the other channels, thus preventing any one channel absorbing appreciable energy from others. Furthermore, it will be seen from Fig. 21 that all the channels are connected at the line transformer and if the filters were not present in each channel, the short circuit of one channel would short-circuit all the other channels.

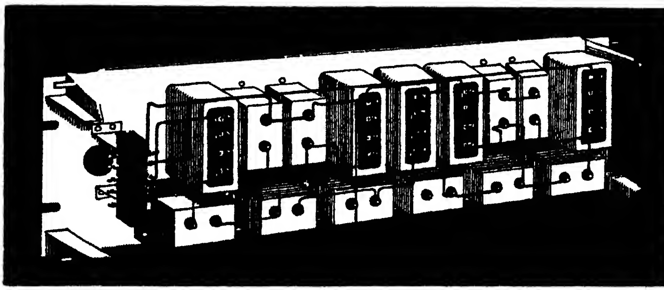


FIG. 14.—A FILTER NETWORK AS MOUNTED. (COVER REMOVED).

An actual filter network, as mounted at the V.F. terminal, is shown in Fig. 14, whilst Fig. 15 shows its attenuation characteristics.

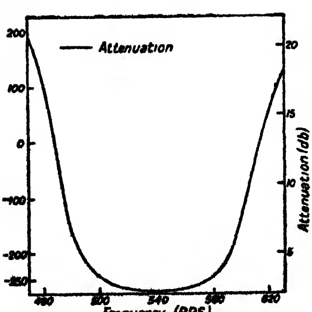


FIG. 15.

Modulation.

The voice frequency alternating current used for a channel in a V.F. system may be represented as shown in Fig. 16 and is known as a carrier current.

If the amplitude of this carrier is caused to vary and

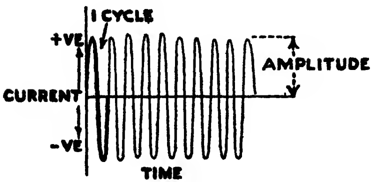


FIG. 16.
THE CARRIER CURRENT.

the variations are controlled by an alternating current of a lower frequency the result would be as shown in Fig. 17. The carrier is said to be modulated.

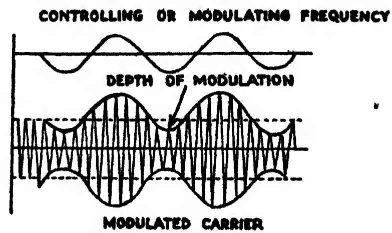


FIG. 17.—IULLSTRATING THE PRINCIPLE OF MODULATION.

It can be shown mathematically that a frequency f_c modulated by a frequency f_m may be considered as consisting of the original carrier frequency f_c together with two other frequencies $f_c + f_m$ and $f_c - f_m$ known as *side-bands*. For instance, if a carrier frequency of 1,500 c.p.s. is modulated by a frequency of 25 c.p.s. the resulting modulated carrier may be considered as consisting of three frequencies: 1,500 c.p.s. (the carrier frequency), 1,525 c.p.s. (the upper side-band) and 1,475 c.p.s. (the lower side-band).

In order to transmit the modulated carrier completely we must transmit the carrier and the two side-bands.

The maximum amount by which the amplitude of the carrier is reduced (when the modulating wave is at its maximum negative value) is usually expressed as a

percentage of the normal value in order to define the extent or *depth* of modulation. If the depth of modulation is 25 per cent, then the amplitude of the carrier will be reduced by a maximum of one quarter of its normal value. If the amplitude is reduced to zero the modulation is 100 per cent.

In V.F. telegraph working the signals from the teleprinter or morse equipment are used to operate the *send* relay which interrupts the carrier current (see Fig. 18). The effect of the teleprinter marking and spacing signals upon the V.F. carrier current is also shown.

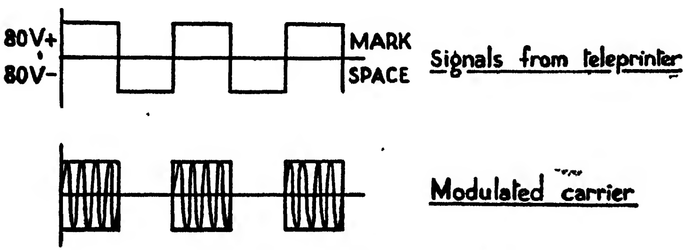


FIG. 18.—SHOWING EFFECT OF TELEPRINTER MARKING AND SPACING SIGNALS UPON THE V.F. CARRIER CURRENT.

The amplitude of the carrier is zero between the signals and we may regard the result as a carrier modulated 100 per cent by a square-topped wave. The teleprinter transmission speed is measured in bauds, but it can be assessed in cycles per second, since positive and negative impulses are transmitted. The upper half of Fig. 18 clearly illustrates this if we assume alternate marking and spacing signals. The teleprinter speed of transmission is equivalent to 25 cycles per second with this condition.

Band Width and Speed of Signalling.

The square-topped telegraph signals may be looked

upon as consisting of a fundamental frequency together with the odd harmonics to infinity. The number of reversals from positive to negative potential per second, divided by two, will give the fundamental frequency and, providing the receiving apparatus will respond to a sine wave form, it is only necessary to consider the fundamental.

Suppose the speed of signalling on a voice frequency channel, with a carrier frequency of 900 c.p.s. is 50 bauds, i.e. equivalent to a frequency of 25 c.p.s., we may regard the carrier as being modulated by a frequency of 25 c.p.s., and, in order to transmit the modulated carrier, we must transmit the carrier frequency of 900 c.p.s. and the two side-band frequencies 900 + 25 and 900 − 25 c.p.s.

This means that for one channel it is not sufficient to have a receiving filter that will admit only the carrier frequency of 900 c.p.s. from the line; we must have a filter that will pass the frequencies 900, 925 and 875 c.p.s., that is, a band pass filter designed to pass the frequencies from 875 to 925 c.p.s. Thus for one channel worked at a speed equivalent to 25 c.p.s., a band-width of 50 c.p.s. is required.

If the speed of signalling is doubled, that is, equivalent to 50 c.p.s., the side-band frequencies will be 950 and 850 c.p.s. and the band-width required is 100 c.p.s.

The greater the speed of signalling the greater is the band-width required for the channel.

Another factor to be considered when deciding on the band-width is the build-up time of the band pass filter. This is the time taken for the alternating current to reach its full amplitude in the filter. The build-up time varies inversely as the band-width of the filter.

Also as the cut-off frequenices of a band pass filter are not clearly defined, we must allow a suitable margin of separation between the boundary frequencies of adjacent channels. Otherwise, the boundary frequency of one channel will pass to some extent through the filter of its neighbour and distort the signals in that channel.

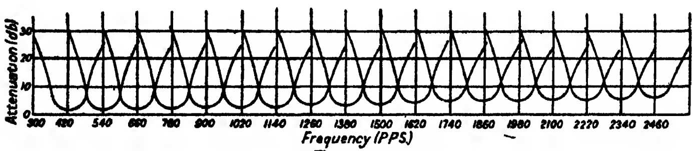


FIG. 19.—THE ATTENUATION CHARACTERISTICS OF THE 18 SEND FILTERS.

The amount of separation depends on an economical compromise between the cost and efficiency of the filters: the more efficient the filters, the less is the separation required.

Fig. 19 shows the attenuation characteristics of the eighteen send filters associated with an 18 channel Voice Frequency telegraph system. It will be seen that the band width of this type of filter is 120 cycles.

The Receiving Equipment.

The receiving equipment consists of:

The receive filters.

The valve amplifiers and detectors.

The receive relays.

Fig. 20 shows a block schematic of the respective position of the receiving equipment of one channel.

It will now be possible to put together in schematic form the *send* and *receive* apparatus associated with one

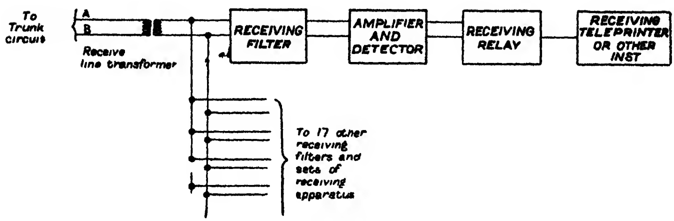


FIG. 20.—THE RECEIVING EQUIPMENT.

channel, thus enabling the transmission of a message in *one* direction and its reception at the distant office. Fig. 21.

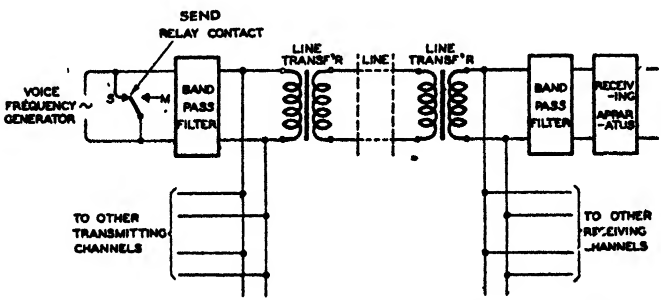


FIG. 21.—SCHEMATIC OF NECESSARY EQUIPMENT FOR MESSAGE TRANSMISSION AND RECEPTION.

The Receive Filters.

The function of the *receiving* filters, which are similar in construction to the corresponding *send* filters, is to divide the multi-frequency signals received over the trunk telephone circuit into the separate channel frequency bands and direct these to the appropriate channel detectors and amplifiers. The circuit of a *receive* filter, which is a two-section filter, is shown in Fig. 22. The

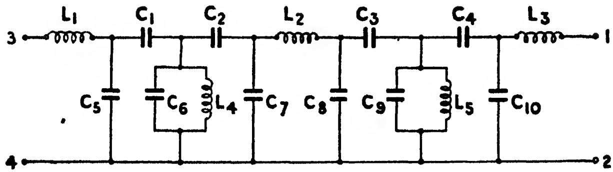


FIG. 22.—THE RECEIVE FILTER.

incoming voice frequency currents pass from the trunk circuit to the receive line transformer and from there to the receive line filters. Each filter selects its own particular band of frequencies and offers high impedance to all other frequencies.

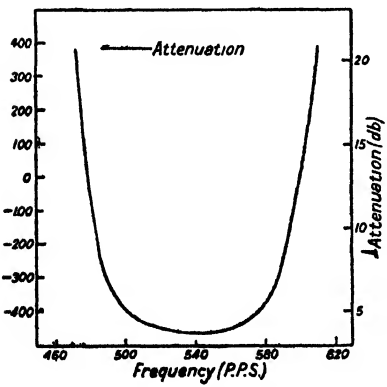


FIG. 23.—ATTENUATION CHARACTERISTICS OF A V.F.T. SYSTEM RECEIVE FILTER.

The output from the *receiving* filters then passes to the valve amplifiers and detectors. Fig. 23 shows a typical attenuation characteristic of a filter used in the system, whilst Fig. 24 shows the characteristics of the eighteen filters.

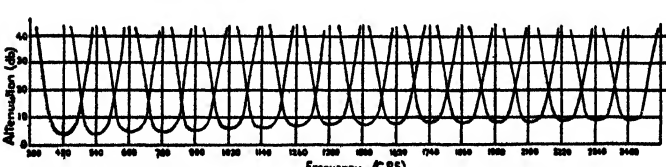


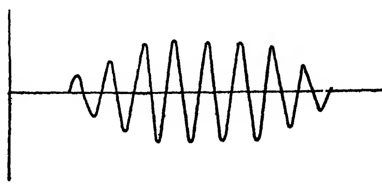
FIG. 24.— ATTENUATION CHARACTERISTICS OF THE RECEIVE FILTERS.

It will be seen that, in effect, the frequency range of the whole system is divided by these filters into eighteen separate bands, and that the centre of each band coincides with the carrier frequency of the particular channel concerned.

The Amplifier and Detector.

The function of the amplifier and detector is to amplify and rectify the incoming carrier current so as to operate the receiving relay which responds to a direct current impulse and to compensate for variations in the strength of the received signals due to variation of repeater gains. The circuit arrangement is shown in Fig. 28. The output from the receiving filter for a *mark between two spacing signals* will be of the form shown in Fig. 25.

FIG. 25.
OUTPUT SIGNAL FROM RECEIVE FILTER (MARK BETWEEN TWO SPACE SIGNALS.)



Oscillations of this type are not suitable for directly operating the receiving relay since it will tend to respond to the rise and fall of each oscillation. It is therefore necessary to rectify the oscillating current. This process, in effect, cuts out the lower half of the oscillations as shown in Fig. 26.

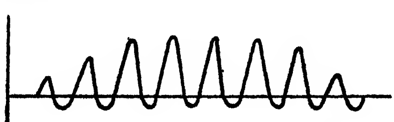


FIG. 26.—WAVE AFTER RECTIFICATION.

The rectified current is still unsuitable for operating the receiving relay which would tend to vibrate in response to the rise and fall in value of the current. This effect is overcome by shunting the operate coil of the receiving relay with a condenser *C* Fig. 28. The resulting current through the relay coil is a smoothly varying one as shown in Fig. 27.

FIG. 27.—CURRENT THROUGH RECEIVE RELAY COIL.

This signal operates the relay and its tongue moves to the marking contact. Because this is a *single current signal*, the relay tongue will remain on the marking contact at the end of signal unless the tongue is restored by some means to the spacing contact at the end of the marking signal. In other words the relay must have a

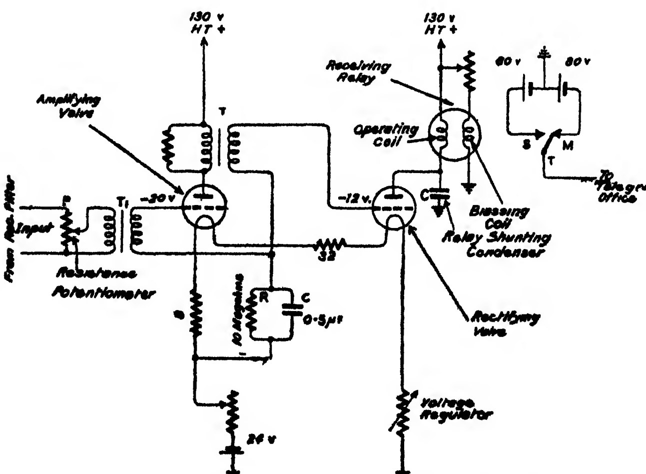


FIG. 28.—THE AMPLIFIER AND DETECTOR CIRCUIT.

spacing bias and under normal conditions be resting on the spacing contact. This is achieved by means of a special biasing coil, see Fig. 28. The above arrangement is necessary because the current flowing in the anode circuit of the rectifying valve is always positive.

Amplifier and Detector (Circuit Operation).

The output of the filters is connected to the primary winding of a step-up transformer via a resistance potentiometer *P* which affords control of the voltage applied to the detector circuit. The secondary winding of the transformer *T* is connected to the grid circuit of the amplifying valve having a high amplification factor. The amplifier valve is coupled to a rectifying valve by an inter-stage transformer *T* and the output of the rectifying valve passes through the operate coil of a receiving telegraph relay.

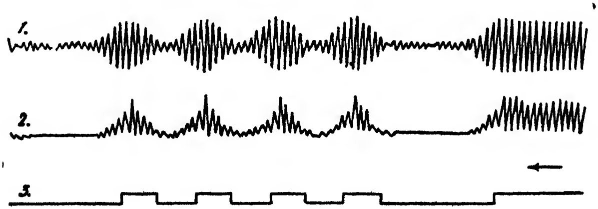
The effect of the received V.F. signals upon the rectifier valve is to cause the anode current to increase or decrease, depending upon whether the signal is a *tone* (marking) or *no tone* (spacing) element. The output of the rectifier valve is thus purely single current, and this necessitates a spacing bias arrangement on the receiving telegraph relay. Bias is obtained by feeding current through the biasing coil of the receiving relay from the H.T. anode supply. This method of biasing renders the relay self-adjusting to variations on the anode battery voltage.

When marking elements of signals are being received then the rectified current produces a preponderating marking current in the operate coil of the receiving relay and the tongue of the relay therefore operates to its marking contact. This extends −80 volt battery to earth via the coils of the electromagnet of the receiving

teleprinter. During spacing elements of signals, V.F. tone is suppressed, the rectifier valve anode current decreases and the receiving relay operates to space under the preponderating influence of the bias current. This operation extends + 80 volts battery to earth via the receiving electromagnet coils of the teleprinter.

Hence the teleprinter signal elements of V.F. tone in the channel are converted to equivalent double current ± 80 V. signals for operating the receiving teleprinter.

The grid bias voltage for the amplifier and rectifier valves is derived from the voltage drop across an 8 ohm resistance which is in series with the filament of the amplifier. The grids are connected to the filament circuit via a 0·5 μF condenser and 10 megohm leak resistance. V.F. signals after amplification are passed to the grid of the rectifier valve causing it to become slightly positive. Grid current therefore flows via the 10 megohm resistance and the P.D. produced across this resistance is impressed upon the 0·5 μF condenser causing it to become charged. The negative bias voltage on the amplifier valve therefore increases negatively,



1. V.F. current at output of receiving filter.
2. Rectified current in winding of receiving relay.
3. Direct current in receiving side.

FIG. 29.—SHOWING STATE OF SIGNALS AT DIFFERENT STAGES OF THE RECEIVING EQUIPMENT.

thus reducing the amplification. During spacing elements of signals the 0·5 μF condenser discharges but, owing to the high resistance discharge path, viz. 10 megohm, the condenser charge remains sensibly constant for the period of the maximum spacing signals.

Hence automatic gain control is obtained and $\pm$ 7½ *db* variations in level of the incoming V.F. signal are permissible without necessitating readjustment of the multichannel voice frequency telegraph equipment.

Fig. 29 shows the shape of the signals at different stages of the receiving equipment.

The Complete Telegraph Circuit.

Fig. 30 shows one complete bothway voice frequency channel extended to two telegraph stations using teleprinters. Signals transmitted by the teleprinter at station **A** are made to operate the receiving electromagnet of the teleprinter at station **B** and vice versa.

Summary of Operations.

The multi-channel voice frequency telegraph system is the name given to a communication system whereby a number of telegraph circuits are obtained from one long-distance telephone trunk circuit.

The eighteen telegraph channels of communications are derived from the use of eighteen different carrier frequencies, namely, 420, 540, 660, 780, 900, 1,020, 1,140, 1,260, 1,380, 1,500, 1,620, 1,740, 1,860, 1,980, 2,100, 2,220, 2,340, and 2,460 c.p.s., which are produced by a multi-frequency generator. One frequency is employed for each channel of communication and this is modulated at the sending end by a static telegraph relay which is controlled by the transmitting telegraph instrument.

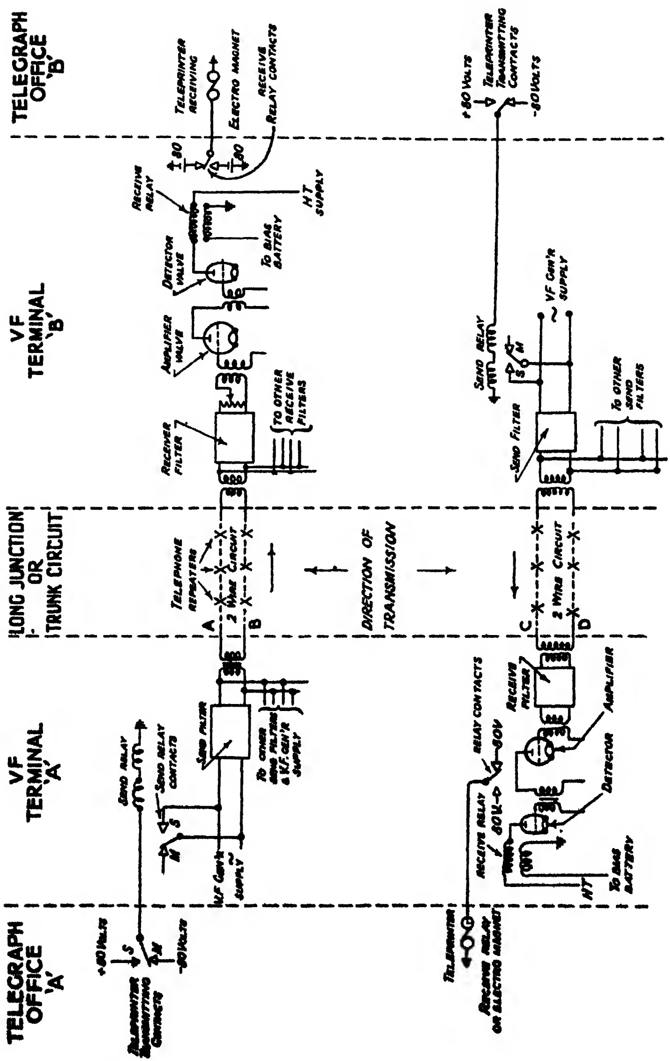


FIG. 30.—TWO TELEGRAPH STATIONS CONNECTED FOR BOTHWAY WORKING OVER A VOICE FREQUENCY CHANNEL.

The modulated carrier frequency is transmitted to the *go* pair of the trunk circuit via a sending band pass filter the characteristic of which is such that it offers minimum impedance to the carrier frequency and a small side band either side of the carrier but a very high impedance to other carrier frequencies. The output from the *send* filter is connected in parallel with that of the *send* filters of channels 2–18 and in series with a line transformer which couples the modulated channel frequencies to the *go* pair. A similar arrangement is employed at the distant V.F. terminal for sending into the *return* pair.

This arrangement permits the use of the same eighteen carrier frequencies for telegraph transmission in each direction in corresponding send and receive channels. During transmission, the eighteen modulated carrier frequencies intermingle in the *go* pair and similarly in the *return* pair and therefore require separation at the respective receiving ends for operation of the individual receiving channel equipment. This is accomplished by connecting the receiving end in each instance to a receive line transformer, the secondary of which is in parallel with eighteen receiving band pass filters. Each filter is designed so that it offers very low impedance to its particular channel frequency and a small side-band either side, but very high impedance to other channel frequencies. Hence the eighteen different channel frequencies are segregated and directed to their respective telegraph channel equipment. With each channel there is associated an amplifier and detector which amplifies and then rectifies the incoming signals so that they operate the receiving relay the tongue of which connects the marking or spacing telegraph voltages to the distant

teleprinter or morse equipment associated with the channel.

The Four and Eight-Channel Voice Frequency Telegraph Systems.

The principle of these systems is similar to that of the eighteen channel system just discussed, except

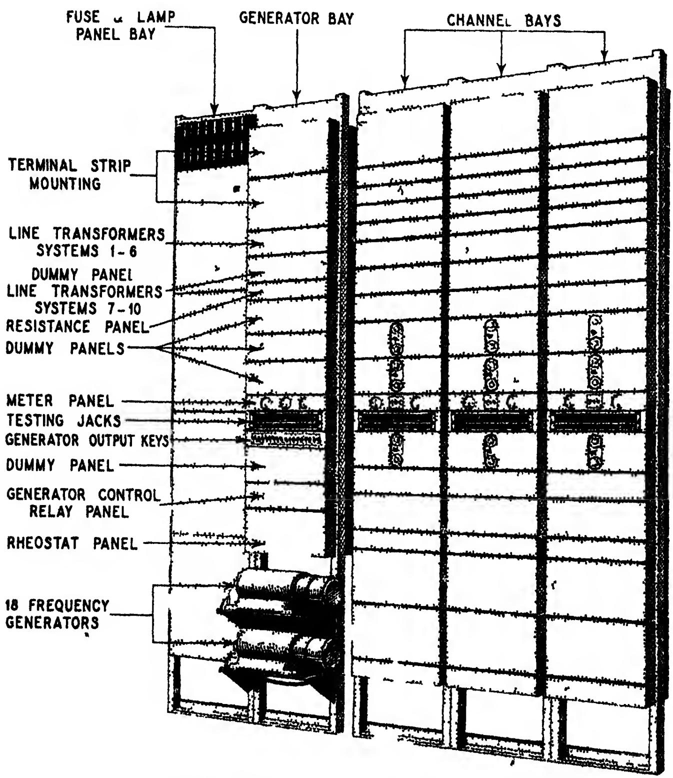


FIG. 31.—FRONT VIEW OF AN EIGHTEEN CHANNEL VOICE FREQUENCY TELEGRAPH SYSTEM.

that the carrier frequencies are produced by valve oscillators (Fig. 4) at the out-stations; separate oscillators and different frequencies being used for each channel as follows:

THE FOUR-CHANNEL SYSTEM.

V.F. Terminal A.

Channel	1	sending	420	c.p.s.	receiving	1,380	c.p.s.
,,	2	,,	660	,,	,,	1,620	,,
,,	3	,,	900	,,	,,	1,860	,,
,,	4	,,	1,140	,,	,,	2,100	,,

V.F. Terminal B.

Channel	1	sending	1,380	c.p.s.,	receiving	420	c.p.s.
,,	2	,,	1,620	,,	,,	660	,,
,,	3	,,	1,860	,,	,,	900	,,
,,	4	,,	2,100	,,	,,	1,140	,,

THE EIGHT-CHANNEL SYSTEM.

V.F. Terminal A.

Channel	1	sending	420	c.p.s.,	receiving	2,100	c.p.s.
,,	2	,,	660	,,	,,	1,860	,,
,,	3	,,	900	,,	,,	1,620	,,
,,	4	,,	1,140	,,	,,	1,380	,,
,,	5	,,	1,380	,,	,,	1,140	,,
,,	6	,,	1,620	,,	,,	900	,,
,,	7	,,	1,860	,,	,,	660	,,
,,	8	,,	2,100	,,	,,	420	,,

V.F. Terminal B.

Channel	1	sending	2,100	c.p.s.,	receiving	420	c.p.s.
,,	2	,,	1,860	,,	,,	660	,,
,,	3	,,	1,620	,,	,,	900	,,
,,	4	,,	1,380	,,	,,	1,140	,,
,,	5	,,	1,140	,,	,,	1,380	,,
,,	6	,,	900	,,	,,	1,620	,,

Channel 7 sending	660 c.p.s.,	receiving	1,860	c.p.s.
„ 8 „	420 „	„	2,100	„

The four-channel voice frequency telegraph system was originally designed to provide four both-way signalling channels over a *two-wire* telephone trunk circuit. As, however, the vast majority of trunk circuits in Great

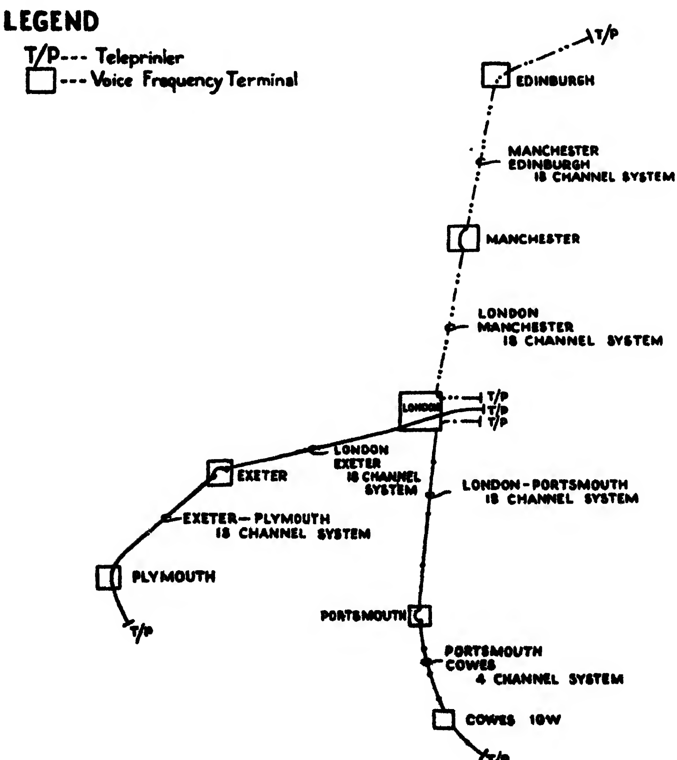


FIG. 32.— ILLUSRTATING THE METHOD OF CONNECTING CHANNELS OF VARIOUS SYSTEMS TOGETHER TO FORM LONG DISTANCE CIRCUITS.

Britain are worked on a four-wire basis, transmission in one direction usually takes place over the *A* and *B* wires, and over the *C* and *D* wires in the reverse direction as in the 8, 12 and 18 channel V.F. systems.

Where a four-channel equipment is installed in a centre accommodating larger voice frequency telegraph systems the valve oscillators are dispensed with and the carrier frequencies are derived from the main voice frequency generator. This type of equipment is termed an *in station* equipment to distinguish it from the *out station* equipment with valve oscillators. Where A.C. mains are available the out-station four-channel terminal equipment derives its power direct from this source, its consumption being approximately 400 watts. Under these conditions each channel is provided with three separate rectifier units. One rectifier unit supplies the valve filaments and anode circuits while the second and third units supply the $\pm$ 80 Volt telegraph supplies to the contacts of the receive relay and those of the telegraph instrument associated with the channel respectively. The in-station equipment is mounted on a channel iron rack 10 ft. 6 in. high by 1 ft. 8½ in. wide, thus this equipment takes the same floor space as one bay of an eighteen-channel system. The out-station equipment is mounted on both sides of a rack 8 ft. 6 in. high by 1 ft. 8½ in. wide.

Method of Routing Long Distance Telegraph Circuits.

A channel in one voice frequency system can be connected in tandem with a channel in another voice frequency system, and in routing telegraph circuits, say from the South of England to the North of Scotland. Channels in perhaps three or four systems may be linked

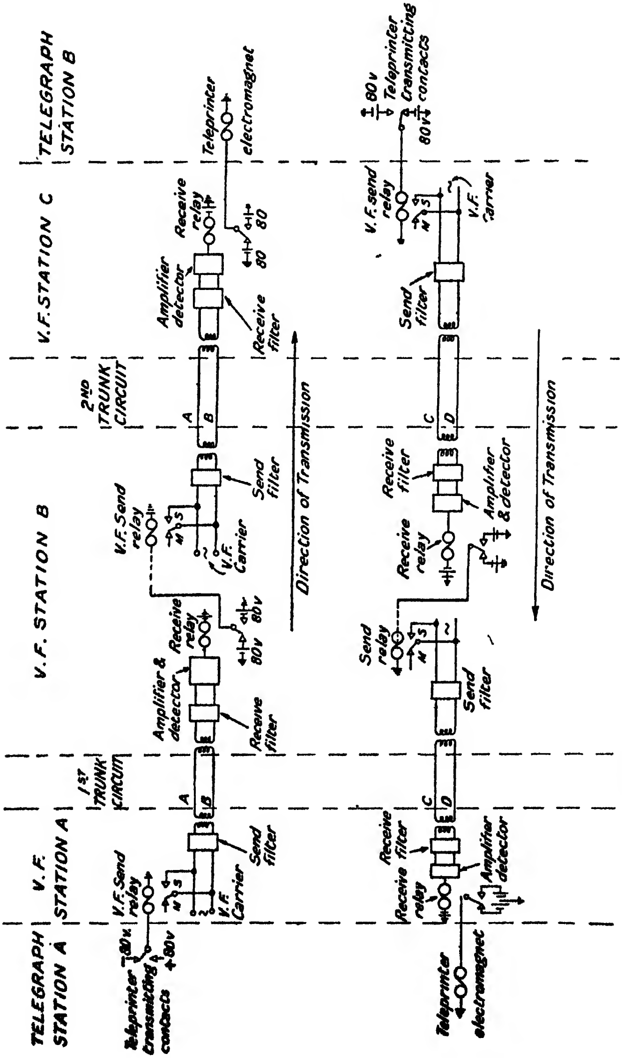


FIG. 33.—METHOD OF ROUTING LONG DISTANCE TELEGRAPH CIRCUITS.

together. Fig. 32 shows how certain telegraph circuits have, in fact, been routed.

In general there is a limit to the number of channels that can be so connected to ensure satisfactory transmission. It depends, of course, upon the type of circuit. For example, on a point-to-point teleprinter circuit (see page 91) five channels could be so connected, whereas switchboard-switchboard circuits are limited to two channels. In the vast majority of cases the latter type of circuit has only one V.F. link, this is because the switchboard-switchboard circuit will subsequently be used to form part of a circuit between two tails off the respective switchboards. The tail circuits may themselves consist of two V.F. links in tandem (see Fig. 34).

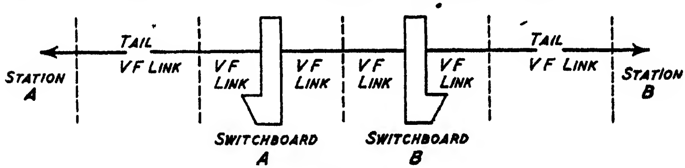


FIG. 34.

This would result in a circuit having six V.F. channels in tandem, which is, of course, rather an extreme case. The circuit arrangements at the intermediate station, with two channels connected in tandem, is shown in Fig. 35.

The signals transmitted by Station **A** operate the voice frequency equipment in the first channel in the usual way, but the tongue of the receiving relay, instead of being wired to the distant telegraph station (as in Fig. 30), is connected to the send relay of the second system. The receiving relay of the second system is connected to the telegraph Station **B**. Thus there is a D.C. and an A.C. conversion at each channel junction point of two V.F. channels.

The joining of one voice frequency channel to that of a channel in another system is effected by means of jumper wires on the cross connection field of the intermediate distribution frame at the intermediate V.F. terminal Station (see Fig. 35). If, however, the connection is only to be of a temporary nature the channels are connected together by means of double-ended plugs and cords on the control panel at the intermediate terminal V.F. Station.

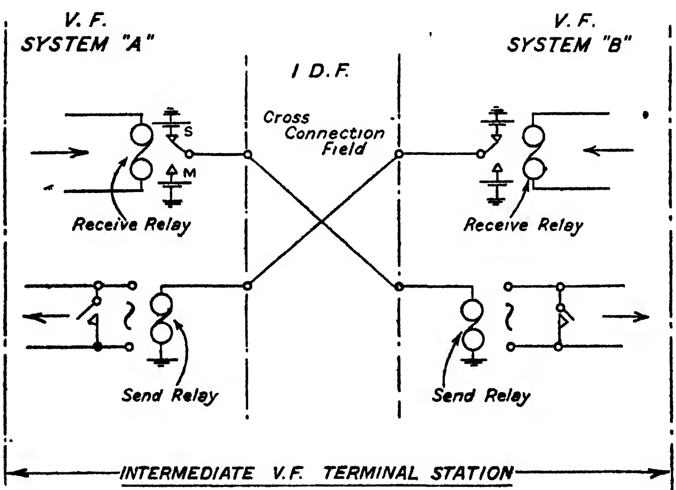


FIG. 35.—CIRCUIT ARRANGEMENT WITH TWO CHANNELS CONNECTED IN TANDEM.

The Eighteen-Channel Voice Frequency Terminal Equipment.

The voice-frequency apparatus is installed in suitable centres. At these locations a specially trained staff is available to deal with the maintenance of the equipment,

which to a large extent follows standard telephone repeater practice. Power supplies at the necessary voltages are available at such stations.

The *equipment is mounted on* channel iron racks each * 10 *ft.* 6 *in. high by* 1 *ft.* 8½ *in. wide.* A fully-equipped terminal of an eighteen-channel 4-wire system comprises:

Three channel bays, each accommodating the apparatus associated with six channels;

One generator bay equipped with two multi-frequency generators, one of which is a reserve;

One fuse bay, which provides the necessary protective arrangements;

One special apparatus bay, through which the direct current extensions are routed for testing purposes; and

One test bay, which provides special testing and measuring facilities essential for the efficient maintenance of the voice-frequency equipment.

Fig. 31 shows the front view of an eighteen-channel voice frequency equipment.

CHAPTER II

THE TELEPRINTER AND THE TELETYPEWRITER

THE teleprinter possesses certain advantages over other forms of communication, these may be summarised below.

SECRECY. It is considered a reasonably secure method of communication; more particularly so when used on a multi-channel voice frequency telegraph system as compared with a physical circuit.

MESSAGES. It provides a printed copy of the message received, or, if desired, several carbon copies. The latter is very desirable in large establishments where more than one department is interested in the message. Simultaneously the transmitting station receives a copy of the message. The latter is referred to as the *local* copy. In the case of cypher messages this is particularly valuable as it enables the sending end to keep an accurate check and thus avoid errors in transmission.

SPEED. A high speed of transmission can be obtained, the maximum speed being 66 words per minute.

Comparison with Morse Signalling.

The training of a morse operator takes many months, whereas a teleprinter operator can obtain a speed of 30 words per minute in eight to ten weeks. Thirty words per minute is a high speed for hand morse, but it is a low speed for teleprinter operating. The

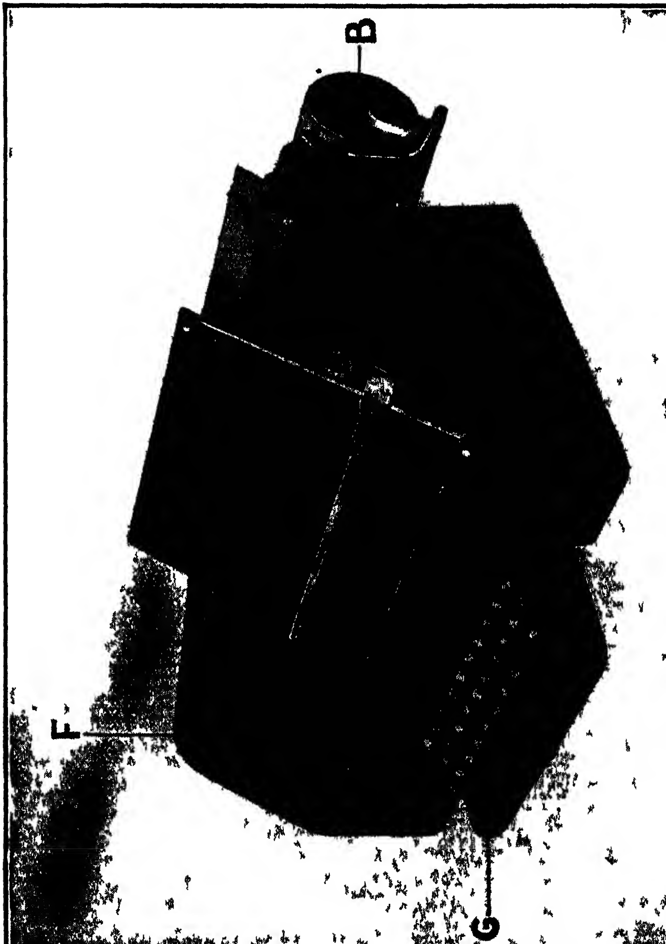


FIG. 36.—THE CREED TELEPRINTER—PAGE MODEL. B–Paper Chariot F–Dust Cover G–Keyboard

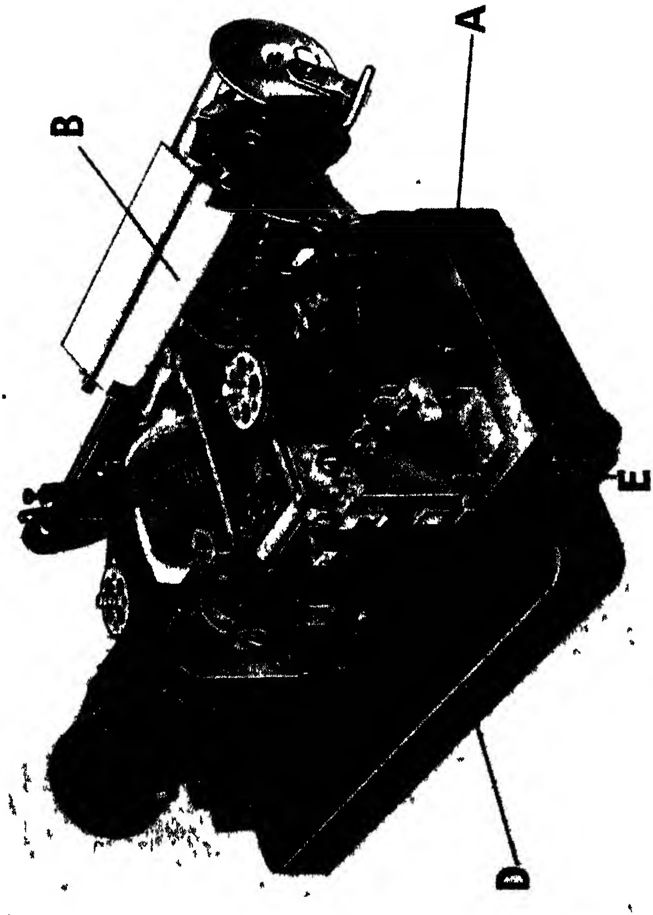


FIG. 37.—RECEIVING-ONLY TELEPRINTER. (Dummy Keyboard D Replacing Normal Keyboard E–Fixing Screws. A–Base. B–Paper in Position.

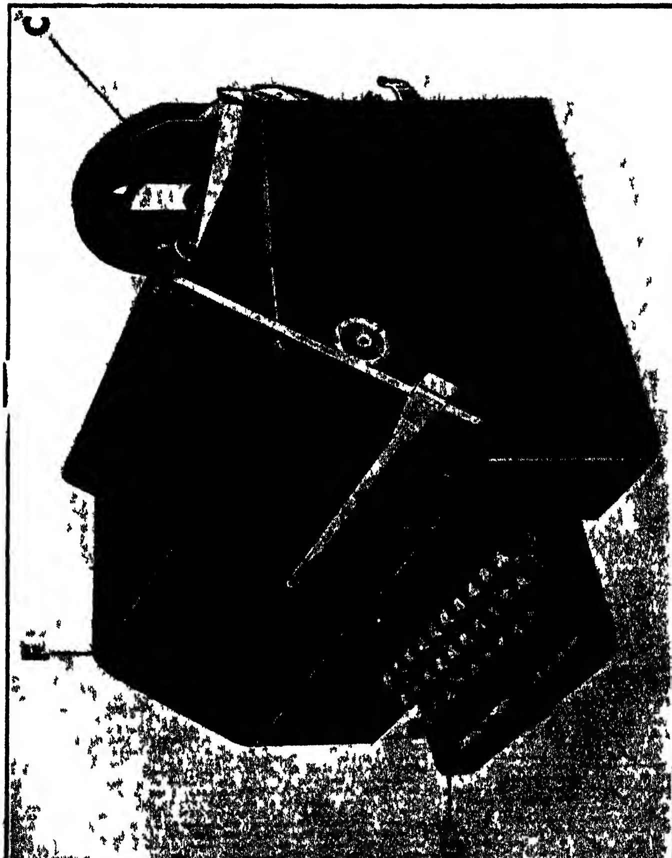


FIG 38—THE TELEPRINTER WITH TAPE ATTACHMENT (C)

teleprinter keyboard is similar to a typewriter keyboard, and, in an emergency, an untrained person could send a message on a direct teleprinter circuit, whereas this could not be achieved on a morse circuit.

The development of voice frequency systems combined with the high speed of operation of a teleprinter as compared with morse, has led to the adoption of the teleprinter as the chief method for passing signals and telegrams.

Construction.

The teleprinter can be divided into two main parts:

The transmitting mechanism.

The receiving mechanism.

These two main parts consist of a number of individual units, each of which can easily be replaced. The transmitting mechanism consists of two such units, namely, the keyboard unit and the transmitting cam sleeve unit.

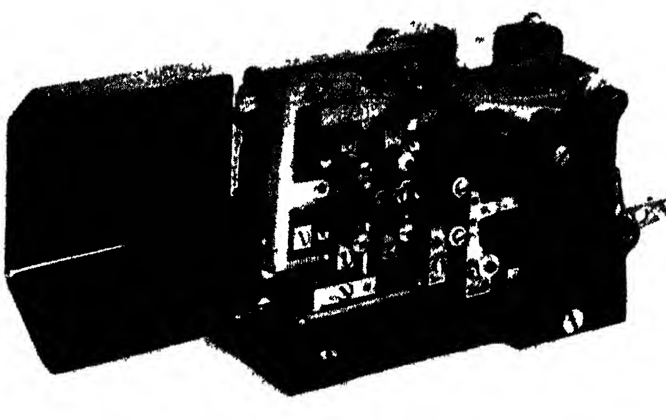


FIG. 39.—ONE FORM OF TRANSMITTING CAM SLEEVE ASSEMBLY.

To transmit a message say from **A** to **B** the operator **A** depresses the relative keys on the keyboard in a similar manner to typewriting. The function of the transmitting mechanism is to convert the depression of a key into a number of electrical impulses which are transmitted to the send line, Fig. 40. At the distant end these electrical

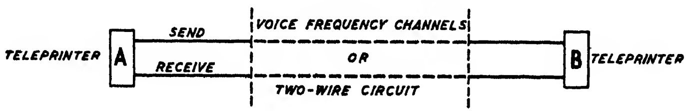


FIG. 40.

impulses operate an electromagnet or relay, the armature of which controls the receiving mechanism, resulting in the printing of a character or letter corresponding to the key depressed at the transmitting end. In a similar manner **B** can transmit to **A** over the other line. The number of electrical impulses sent to line for each key depression is seven. The first impulse is a *start* signal, and this starts the teleprinter motor at the distant station. This is then followed by five further electrical impulses which form the intelligence code corresponding to the key depressed. The last impulse to be sent is the *stop* signal, which is designed to stop the receiving mechanism of the receiving machine.

The teleprinter intelligence code is shown in Fig. 41, and the keyboard in Fig. 42. It will be seen from Fig. 41 that the same code is used twice, once for letters and once for figures, e.g. *A* and— or *E* and 3; this is because with the five-unit code used, only thirty-two different combinations are available, whereas the keyboard is required to include a much greater number of characters. To obtain sixty-four different combinations an inversion

		START ○ — CODE IMPULSES 1 2 3 4 5 — STOP ●			START ○ — CODE IMPULSES 1 2 3 4 5 — STOP ●
A	–	●●○○○	P	0	○●●○●
B	?	●○○●●	Q	1	●●●○●
C	:	○●●●○	R	4	○●○●○
D	WHO ARE YOU	●○○●○	S	'	●○●○○
E	3	●○○○○	T	5	○○○○●
F		●○●●○	U	7	●●●○○
G		○●○●●	V	-	○●●●●
H		○○●○●	W	2	●●○○●
I	8	○●●○○	X	/	●○●●●
J	BELL	●●○●○	Y	6	●○●○●
K	(	●●●●○	Z	+	●○○○●
L	)	○●○○●		CAR. RET	○○○●○
M	.	○○●●●		FIGS	●●○●●
N	,	○○●●○		LTRS	●●●●●
O	9	○○○●●		LINE FEED	○●○○○

SPACE ○○●○○

KEY:- ● = MARK
○ = SPACE

FIG. 41.—THE TELEPRINTER SIGNALLING CODE.

mechanism, Fig. 55, is introduced which is actuated by the letter shift and figure shift keys. The position of this mechanism determines whether a letter or a figure is printed. The printer apparatus is so arranged that all combinations received between the receipt of a *letter shift* signal and a *figure shift* signal cause letters to be printed. Conversely, between the receipt of a *figure shift* signal and a *letter shift* signal figure characters will be printed. The *mark*

and space elements, forming the code trains in Fig. 41, are of 20 milliseconds' duration each.

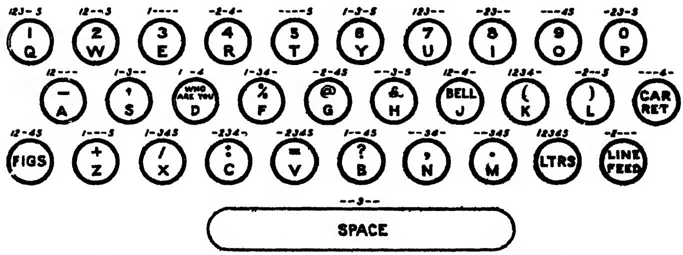


FIG. 42.—THE TELFPRINTER NO. 7 KEYBOARD.

The keyboard layout shown in Fig. 42 is similar to that of an ordinary typewriter. Some of the keys perform non-typing functions, e.g. by the depressing of the *who are you* key the identity of the station to whom connection has been established can be ascertained (see also p. 73). The line feed key moves the paper forward on both the sending and receiving teleprinters. The depression of the J *bell key* rings a bell associated with the distant end teleprinter indicating that the services of the teleprinter operator are required. The depression of the carriage return key at the end of a line returns the paper carriage for the printing of the next line. The space bar performs two functions, in addition to its ordinary function of providing spaces between words, it acts as a calling device (see p. 92).

Transmitting Mechanism.

This mechanism consists essentially of two main units, viz:

(*a*) The Transmitting Cam Sleeve Assembly. (Figs. 39, 43 and 44).

(*b*) The Keyboard.

The transmitting cam sleeve assembly incorporates the clutch trip mechanism. This consists of a cam sleeve which is at rest normally, and which controls all the mechanical operations of the transmitter. When any key lever of the keyboard is depressed a motor-driven spindle causes the cam sleeve to make one revolution and then stop. This is effected as follows: (Fig. 43).

The ratchet wheel *RW* is driven continuously by the motor in the direction shown. Pivoted on the cam sleeve *CS*, which surrounds *RW*, are two pawls *E*. The pawl abutment *D* holds these pawls, normally, in such a position that their hooked ends do not engage with the teeth of *RW*.

On depressing a key lever, the trip bar *A* moves downwards, Fig. 43, causing the upper end of the bellcrank *C*

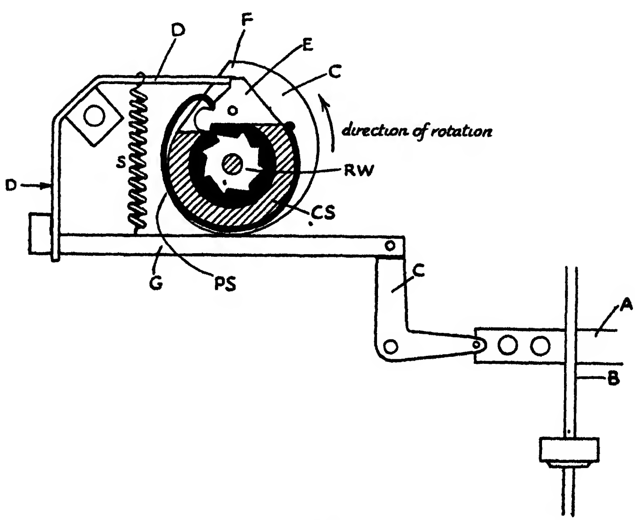


FIG. 43.—ILLUSTRATING THE ONE REVOLUTION CLUTCH MECHANISM.

to move the cam trip lever *G* to the right. The latter engages with the lower end of the pawl abutment *D*, thereby lifting the upper extremity away from the pawls *E*. Immediately this occurs, the pawl spring *PS*, encircling the cam sleeve, forces the hooked ends of the pawls into engagement with the ratchet wheel and the cam sleeve with its various cams commences to rotate. One of the cams *C*, as it rotates, pushes the lever *G* down until it disengages from the forked end of the pawl abutment *D*; the latter is then restored to its original position by the spring *S* so that its upper end is in position to

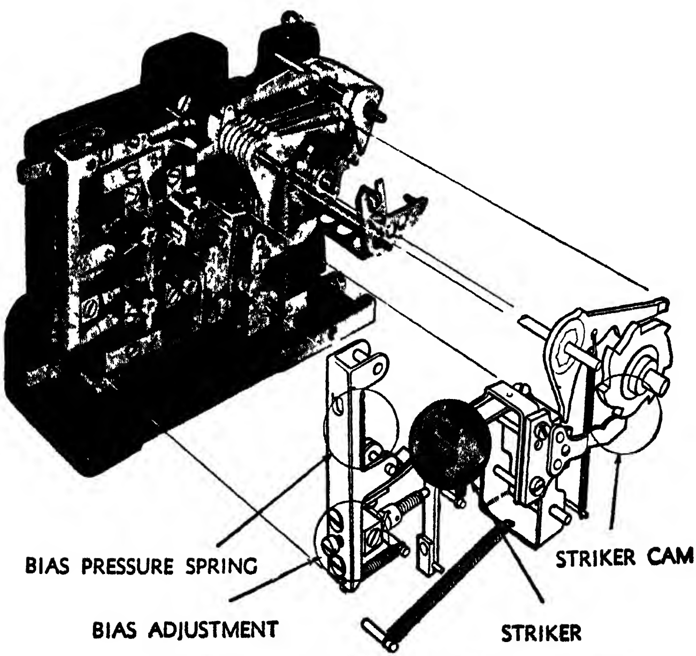


FIG. 44.—THE STRIKER TYPE TRANSMITTING CAM SLEEVE ASSEMBLY.

intercept the pawls E, withdraw them from the ratchet wheel and thus stop the cam sleeve at the end of one revolution.

Underneath the key levers and at right angles to them are the Locking Bar No. 1 and the Five Combination Bars CB_1 to CB_5, as shown in Fig. 45. The upper edges of the latter have a series of projections (CP) arranged in accordance with the signalling code. Normally the bars are held to the left against the tensions of their springs, by the lower end of the reset lever (RL), so that the projections do not come directly under the key levers. A key when depressed can therefore enter a set of notches between the projection of the combination bars. Subsequently those combination bars without projections will move to the right: the projections on the other bars riding against the key lever hold them stationary. The projections correspond to spacing units of the code, and the code for any particular key lever may be ascertained from the projections immediately to the left of it. Thus for H (see Fig. 45) the code is 1, 2 and 4, spacing and 3 and 5 marking.

Each combination bar has a vertical extension at the resetting lever end and associated with it is a selecting lever, which is constrained by springs to ride on the surface of a cam on the cam sleeve. There are five selecting levers. SL_1 to SL_5 and five cams, TC_1 to TC_5 corresponding to the five combination bars. In addition there is a sixth selecting lever, the start stop selecting lever SSL, operated by a sixth cam TC, but there is no combination bar associated with SSL. The function of SSL is to send the *start* impulse. The lower ends of all the selecting levers bear against the upper part of the contact lever CL, to which is attached the contact

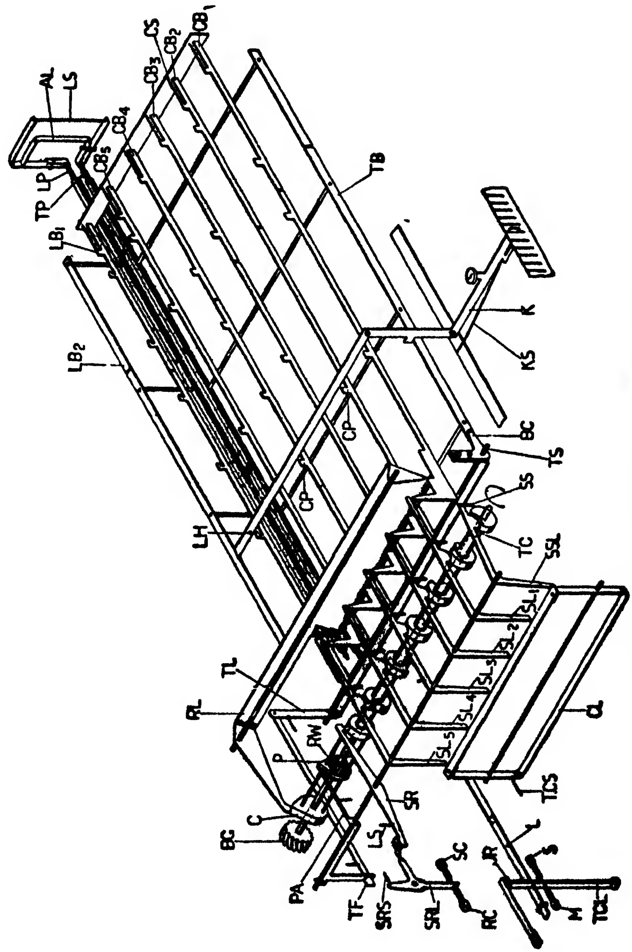


FIG. 45.—THE TRANSMITTING MECHANISM.

operating link, the forked end of which embraces the insulated end of the transmitting contact lever *TCL.* The latter plays between the spacing and marking contacts to which is connected the line signalling battery. Normally, the transmitting tongue rests against the marking contact.

The action of the transmitter may be best explained by considering the following sequence of events occurring during the transmission of, say, the letter H, the code for which is 1, 2 and 4, spacing, 3 and 5 marking.

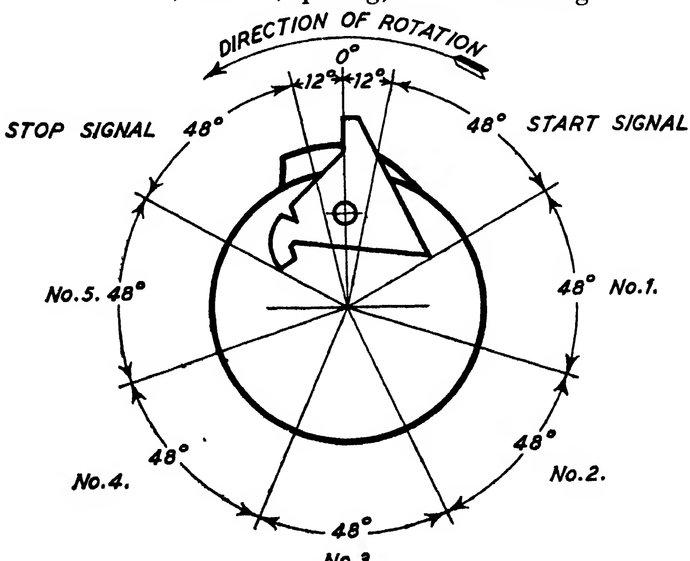


FIG. 46.—DIAGRAM ILLUSTRATING THE SEQUENCE OF THE TRANSMITTED SIGNALS IN ONE REVOLUTION.

(*a*) When key lever H is depressed it enters the notches in the combination bars, operates the trip bar which releases the cam pawls, thus causing the came sleeve to rotate (see Fig. 45).

(*b*) The rotation of the resetting cam allows the resetting lever to release the combination bars together with locking bar No. I. The latter proceeds to lock down key lever H, combination bars 3 and 5 are pulled to the right by their springs; *CB*1, 2 and 4 remain stationary since their projections butt against the depressed key lever. Accordingly, the combination bars *CB*3 and *CB*5 will move from under the ends of SL_3 and SL_5 but *CB*1, *CB*2 and *CB*4 will remain under the ends of SL_1, SL_2 and SL_4.

(*c*) As the cam sleeve rotates the projection on *SSL* will rise out of the indent in the cam track *TC*. The lower end of *SSL* will therefore move to the right under the tension of the transmitting cam spring *TCS* causing the operating lever *CL* to turn clockwise (since it is pivoted at its centre) so that the upper part with associated lever *L* moves the transmitting contact lever *TCL* to the "spacing" contact *S*. This gives the start impulse.

(*d*) As the cam sleeve moves round SL_1 tends to fall into the indent in the first cam track but cannot do so because *CB*1 has not moved to the right. A second spacing signal is therefore transmitted.

Next SL_2 tends to drop in the second cam indent but is unable to do because *CB*2 is in its normal position, thus another spacing signal is transmitted.

The cam sleeve continues to rotate and SL_3 falls into the indent in cam track *TC*3,

since combination bar *CB*3 has moved to the right. Consequently the transmitting contact lever *TCL* will move to the marking contact. Similarly cams 4 and 5, will in turn, cause the contact operating lever to move the tongue to *S* and *M* respectively.

(*e*) When SL_5 rides out of the indent in cam 5 the transmitting tongue remains at marking since *SSL* falls into the indent in *TC* and shortly afterwards cam *C* operates the resetting lever restoring the combination bars and LB_1 The latter releases the depressed key lever which is restored to normal.

(*f*) Finally the clutch is disengaged by the action of the pawl abutment, and the cam sleeve comes to rest after making one revolution.

Locking Bars.

In order to ensure accurate operation of the keyboard, two locking bars are provided. The first locking bar LB_1 (Figs. 45 and 47) is arranged to hold down the key which has been depressed until the transmission of the five combination signals has been effected and the second locking bar LB_2 is arranged to prevent the depression of a second key until the first key has been released. The relative positions of LB_1 and LB_2 are clearly shown.

The projection on locking bar 1 engages with the locking hole of the depressed key (Fig. 47) and maintains the key in the depressed position. The locking bar No. 2 is actuated in the following manner. The keybar projection (Fig. 47) turns bar *TB* on its pivot. A spring system couples *TB* with locking bar No. 2 and causes it to move over on top of the depressed key. As LB_2

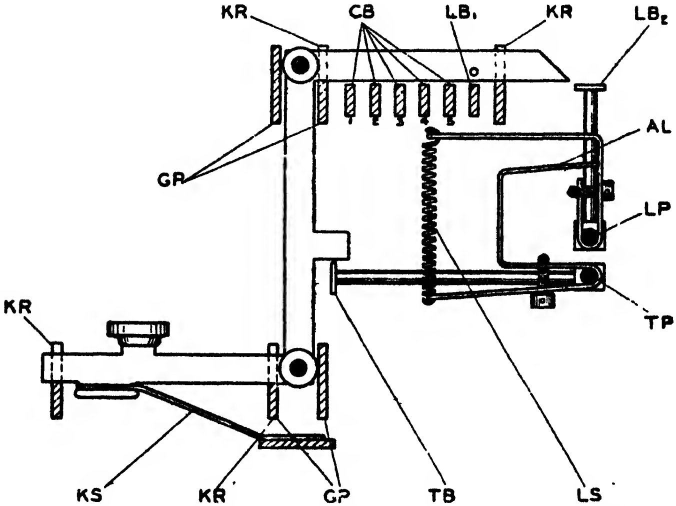


FIG. 47.—ILLUSTRATING THE ACTION OF THE LOCKING BARS.

extends the whole length of the keyboard (Fig. 45) no other key can be depressed until the transmitting shaft has completed one revolution.

Transmission over a Single Conductor.

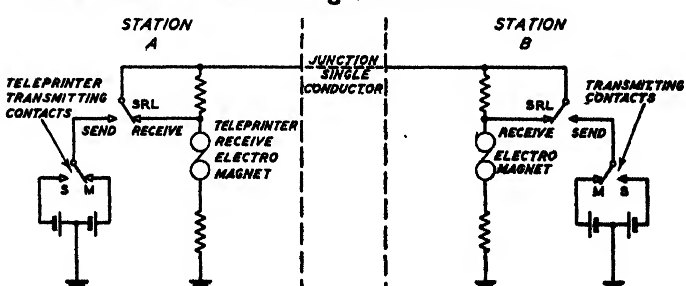


FIG. 48.—TRANSMISSION OVER A SINGLE CONDUCTOR.

Teleprinter communication can be established over a single conductor as shown in Fig. 48. The transfer from sending to receiving and vice-versa is achieved by means of an automatic *send–receive* switch *SRL*. However, this method is seldom used, due mainly to the large use of voice frequency channels. All teleprinters are, however, fitted with an automatic *send–receive* switch to enable a *local* copy of the message being sent to be obtained.

Action of the Send–Receive Switch.

The *send–receive* switch is controlled by the switch lever *SR*, Fig. 45. Normally the *send–receive* switch is held against the *receive* contact, but immediately the transmitting cam commences to rotate, the *send–receive* switch lever turns about its pivot under the action of the lever restoring spring *LRS* and the switch is moved to the *send* contact, in which position it remains until the revolution of the transmitting cam is completed. It is then returned to normal, that is, to the *receive* contact.

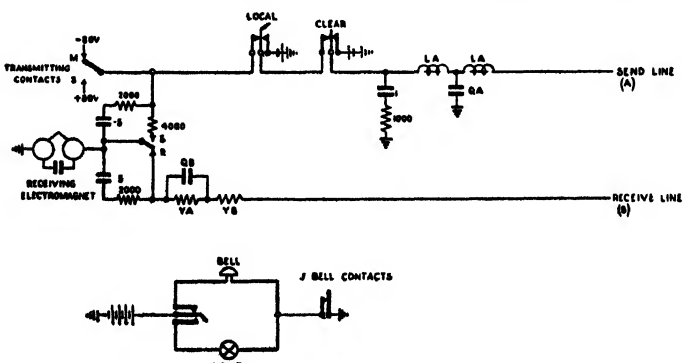


FIG. 49.—METHOD OF OBTAINING A LOCAL COPY OF MESSAGE BEING TRANSMITTED.

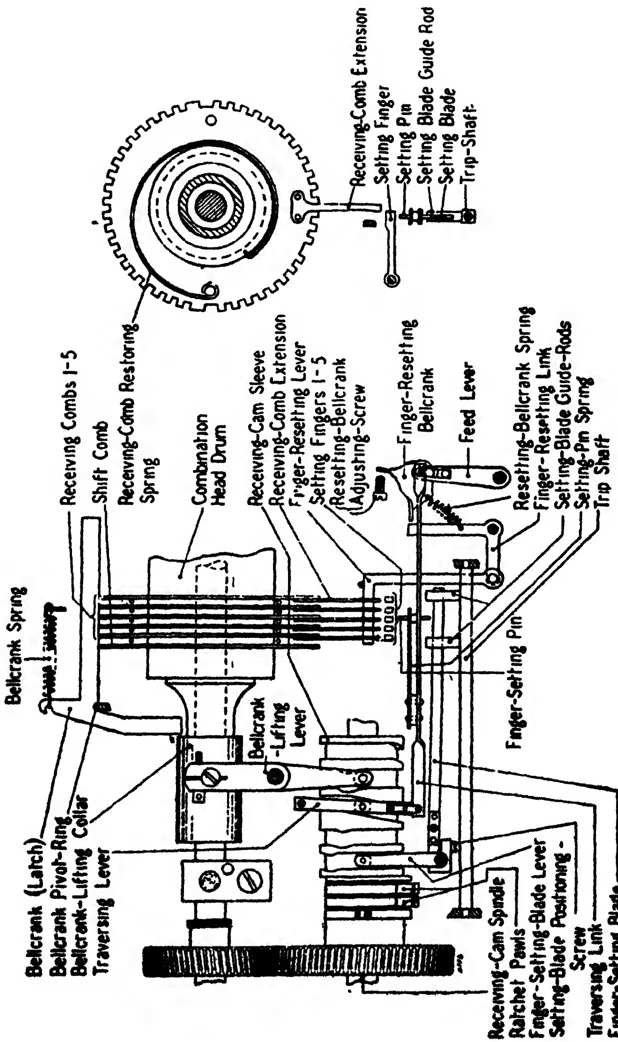


FIG. 50.—THE SELECTING MECHANISM.

Method of Obtaining Local Copy.

The diagram shown in Fig. 49 illustrates the method of obtaining a local copy of the message being transmitted. When the teleprinter is transmitting, the *send–receive* switch moves over to the *send* contact (*S*) and thereby completes a circuit via the 4,000 ohm resistance for the receiving electromagnet to operate. The armature of the electromagnet controls the receiving mechanism.

The Receiving Mechanism.

The signals generated by the transmitting mechanism pass to line and the distant teleprinter. Here they operate the receiving electromagnet which in turn controls the receiving portion of the teleprinter. This comprises the receiving cam, the selecting mechanism, the translating mechanism, Fig. 50, and the printing mechanism. The selecting mechanism comprises the traversing link, the finger setting pin, the finger setting blade and the setting fingers. The correct sequence of the selecting operations is ensured by the five tracks in the receiving cam sleeve, in each of which there runs a roller controlling the movement of a lever.

A development of the five cam tracks of a receiver cam is shown in Fig. 51. The rollers attached to the cam levers are shown in the position which they occupy in the tracks when the cam is held stationary by the pawls.

As the armature of the electromagnet responds to the incoming signals its associated link causes the trip shaft to be turned in one of two positions corresponding to these signals (see Fig. 52).

The trip shaft performs the following functions:

(*a*) It controls the rotation of the receiving-cam sleeve, by engagement or disengagement of

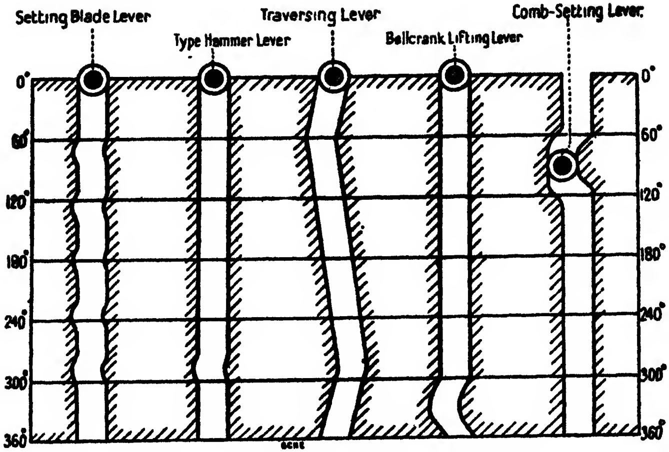


FIG. 51.—THE RECEIVING CAM TRACKS.

the pawls through the action of the pawl abutment.

(*b*) It guides the finger-setting blade, so that the correct combination is set up on the comb-setting fingers in accordance with the incoming signal combination.

The former is achieved in the following manner: The receiving cam sleeve is fitted with a clutch of a type similar to that attached to the transmitting cam sleeve, and as long as the line current is marking, the clutch pawls (only one of which is shown) are held out of engagement by the receiving pawl abutment, Fig. 52. When, however, the first spacing signal is received, the trip shaft turns in the direction indicated by the arrow, and so withdraws the pawl abutment away from the pawls; this allows the pawl springs to force the hooked ends of pawls into engagement with the rotating teeth

of the ratchet wheels and the cam sleeve commences to rotate. The *start* signal which precedes the five code pulses is a *spacing signal*, and this operates the clutch mechanism so that the receiving mechanism is ready to receive the following code impulses. Although during the reception of a five-unit signal combination the pawl abutment moves in and out of the path of the pawls, it does not engage with them because the pawls accompany the cam sleeve in its rotation and only approach the pawl abutment again just as the cam sleeve is completing its revolution. The trip link then holds the abutment firmly in the path of the pawls which are thereby withdrawn from the ratchet.

The traversing lever is attached to the traversing link to which it imparts a reciprocating movement. This link carries the finger-setting pin, which is normally held against the link by the finger-setting spring, but may be moved away from it when struck by the finger-setting blade. Opposite the end of the finger-setting pin are five comb-setting fingers pivoted at their lower ends on a spindle which may be lifted vertically by the operation of the comb-setting lever. In the rest position the finger-setting pin is opposite comb-setting finger No. 3.

When the cam sleeve revolves, the traversing link is traversed first to the left until the finger-setting pin is opposite finger 1, then to the right until the pin is opposite finger 5, finally returning to its normal position opposite finger 3, as the cam completes its revolution.

The timing of this operation is such that the finger-setting pin is opposite the first setting finger during the receipt of the first code element of the signal train transmitted by the distant teleprinter, and opposite the second, third, fourth and fifth setting fingers during the receipt

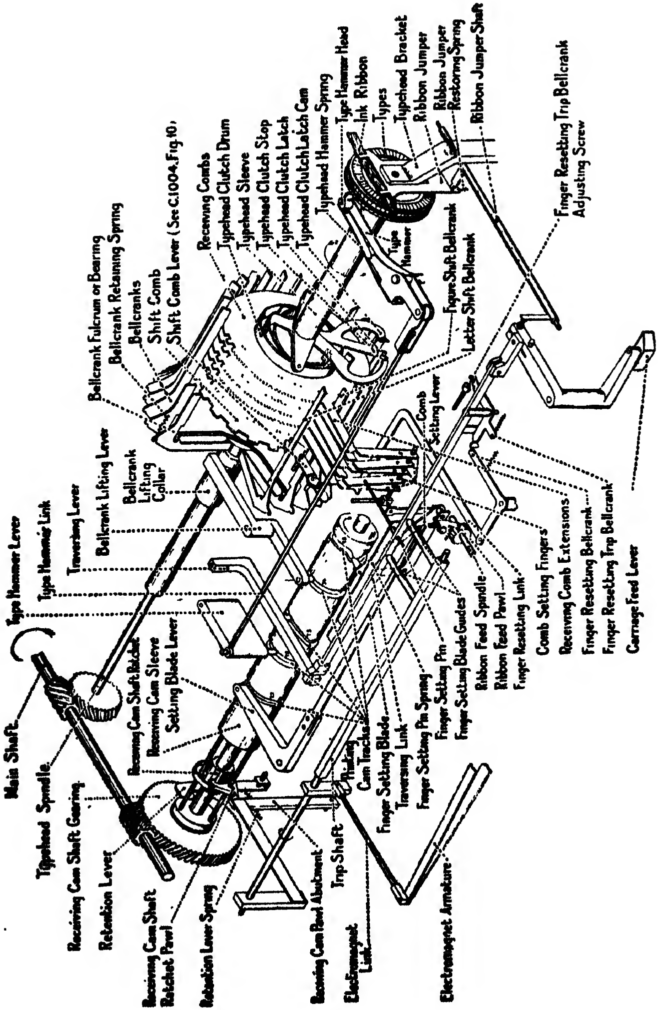


FIG. 52.—THE TELEPRINTER RECEIVING MECHANISM.

of the following code elements respectively. Simultaneous with this movement of the finger-setting pin, the finger-setting blade is arranged to be moved forward and backward in timed relation to the movement of the finger-setting pin past the setting finger. Furthermore the finger-setting blade is arranged to be moved up and down by the control of the trip shaft so as to be opposite the finger-setting pin when the trip shaft is in a position corresponding to a mark signal and to be below the level of the finger-setting pin when the trip shaft is in a position corresponding to a spacing signal. Thus for a marking signal the forward operation of the finger-setting blade moves the finger-setting pin forward so as to push the corresponding comb-setting finger underneath a receiving comb extension, but for a spacing signal, the finger-setting blade moves below the setting pin and the corresponding finger is not moved.

After the finger-setting pin returns from its forward stroke on the fifth comb-setting finger the comb-setting lever operates (Fig. 52) and lifts the comb-setting fingers. The receiving comb extensions having fingers underneath them are raised and the respective combs revolve slightly. The receiving combs have a number of slots cut in their periphery in a definite manner and when one or more combs are turned in the manner just explained, adjacent sets of slots become aligned across the five combs at a particular point, depending upon the character received, and *one* of sixty bell-cranks which surround the combs will fall into the aligned sets of slots, and lock the combs (see Figs. 50 and 52).

The type wheel, which is driven by a friction clutch, is provided with a stop arm adapted to be caught by any selector bell-crank which has fallen into an aligned set of

slots so as to be arrested and thus bring opposite to the printing hammer the type bar required. The actual printing of the character just selected does not take place until near the end of the next revolution of the cam sleeve, just as the setting blade moves towards the fifth setting finger.

At this instant, the indent in cam T_2 operates the type hammer lever, causing the type hammer to sweep forward and strike the type bar selected by the previous combination of signals, and thus record a character on the paper.

Resetting of the Setting Fingers.

The fingers are reset at the commencement of the following revolution of the cam sleeve during the reception of the start signal. During the movement of the traversing link to the left, from finger 3 to finger 1, the finger-resetting trip bell-crank turns the finger-resetting bell-crank about its pivot, thus causing the finger-resetting link to pull forward those fingers which have been pushed under the receiving comb extensions previously. The finger-resetting bell-crank adjusting screw is so adjusted that the finger-resetting trip bell-crank is tripped out of engagement with the finger-resetting bell-crank at the instant when the fingers have been moved into their correct positions. Simultaneously, with the resetting of the fingers by the finger-resetting link, the right-hand end of the comb is depressed by the action of the cam and the spindle carrying the five fingers is lowered into such a position that the upper ends of the fingers are opposite the end of the setting pin. As the traversing link moves to the left, the setting-blade lever and the finger-setting blade remain stationary.

Re-setting of Fallen Latch.

The bell-crank lifting lever serves to restore the fallen bell-crank or latch during the next revolution of the cam shaft, the action taking place just prior to the instant when the comb-setting fingers are raised by the comb-setting lever. This action is achieved in the following manner. The bell-crank lever rides in cam track T_4 and its other end engages with the bell-crank lifting collar. The shape of the cam track causes the lifting collar to move inwards and then outwards from the bell-cranks. During the forward movement the bell-cranks or latches are lifted from the edges of the receiving combs. Thus the latch used for the last character is withdrawn from engagement with the type-head clutch which then commences to rotate again.

FIG. 53.—THE RECTIFIER UNIT ASSOCIATED WITH A TELEPRINTER WORKED FROM A.C. MAINS.

Printing (Page Printer).

The printing is effected upon a sheet or web of paper, carried by a paper carriage which is moved endways in a step-by-step manner. For every letter received this movement winds up a spring

contained in a spring drum which acts to return the carriage to the beginning of the line when it is released by the carriage return signal.

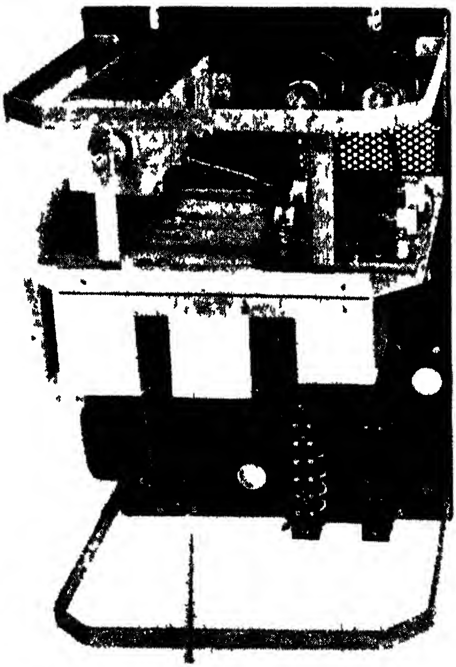


FIG 54—THE RFCTIFIER UNIT WITH COVER REMOVED.

Paper Carriage.

The paper carriage is arranged to carry the roll of paper to and fro in order to avoid the necessity for providing a long loop of paper which is required if the paper roll were fixed. Thus it is unnecessary to cut the table on

CAMTRACKS.

	Finger Setting Blade.	*Type Hammer.*	*Traversing Link.*	*Bellcrank Lifting Lever.*	*Comb Setting Lever.*
Impulses Start	—	—	Traversing Link: Moves pin to finger one—Lowers Ribbon Jumper—Resets Fingers.	—	Lowers Fingers and Feeds Ribbon Along.
1	Finger Setting Blade Makes First Sweep.	—	Moves Finger setting pin from one to five Moves Ribbon gradually upwards Resets Finger Resetting Trip Bellcrank	—	—
2	Second Sweep.	—		—	—
3	Third Sweep.	—		—	—
4	Fourth Sweep.	—		—	—
5	Fifth Sweep.	Type Hammer Makes Sweep Forward and back.		Bellcrank Lifting Collar.	—
Stop	—		Ribbon Jumper commences to Lower. Finger Setting Pin Returns to Centre.	Functions (Holds Bellcranks Lifted—Drops Bellcranks	Lifts comb Setting Fingers and Lifts Ribbon Feed Pawl into next Tooth.

which the machine is mounted and it can be used on any normal table just as an ordinary typewriter. It also facilitates the provision of special silencing covers where maximum quietness is required.

Summary.

The sequence of receiving operations during one revolution are summarised in table.

The Inversion Mechanism.

Since there are only thirty-two useful combinations of the five-unit code, the numerical and other special

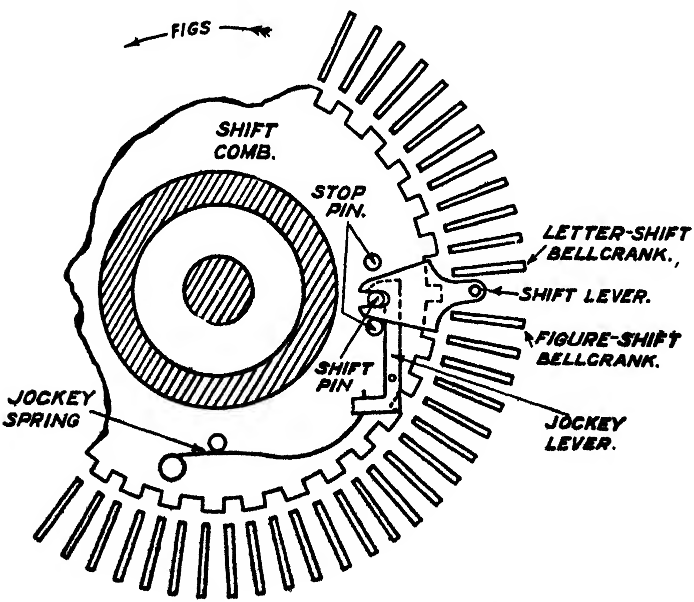


FIG. 55.—INVERSION MECHANISM.

signals are operated by the same code combination as that employed for letters, but before doing so a signal is sent called the *figure shift*. The change from figures to letters is accomplished by a signal called the *letter shift*. These signals are transmitted by the operation of special bars. At the receiving machine these shift signals cause the operation of the inversion mechanism (see Fig. 55).

Of the six receiving combs with which a teleprinter is equipped, five are used for the five-unit code and the sixth for determining whether the selected character shall be printed as letters or figures (see Fig. 50). When a selection is set up by movement of one or more of the five-unit combs, a line of indentations is opened beneath two adjacent latches, the particular latch operated being determined by the sixth comb. This comb which has a number of equally-spaced slots around its periphery, can occupy one of two positions. In one position it permits only letter latches to be selected and in the other position only figure latches can be selected.

The movement of the sixth comb is effected by the inward movement of either the letter shift or the figure shift latch. On the reception of, say, the figure shift signal, combs 1, 2, 4, and 5 are moved slightly and a line of indentations is set up into which the figure shift bell-crank or latch drops. This latch in dropping, presses on the shoulder of the shift lever *SL*, Fig. 55. The forked end of the latter, in acting on the shift pin, turns the shift comb in an anti-clockwise direction to the figures position and all selections following this will give secondary or figure characters. The change back to letters is effected when the letter shift latch is selected and moves *SL* in a clockwise direction to the letters position.

The Answer Back Unit.

To enable a calling station to verify that the distant station to whom connection has been established is correct, all teleprinters are fitted with an *answer back* unit. The identity of the distant station is established by depressing the *who are you* key on the calling teleprinter. This operates the answer back unit of the distant teleprinter, which results in the transmission back of its code or number. This unit also provides a means of ensuring that the apparatus at both ends of the circuit is satisfactory.

Upon the depression of the *who are you* key, the answer back signal bell-crank is operated on the called machine and this releases the answer back drum which is thus rotated by the friction clutch. As this rotates, the cam through its associated trip lever operates the trip bar,

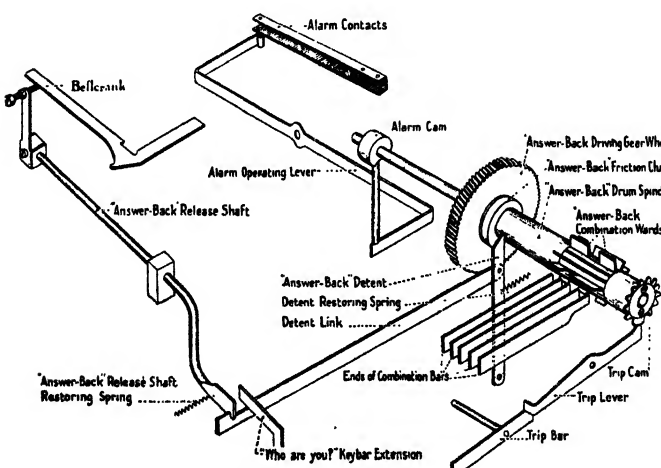


FIG. 56.—ANSWER BACK UNIT.

thus releasing the transmitting cam which allows the combination bars to set back against the first ward on the answer back drum which has been moved into line with them (see Fig. 56).

The operation of the transmitting cam thus sends the signals corresponding to the first ward on the drum just as if a key had been depressed on the keyboard. The transmitting cam then comes to rest and as the drum continues to rotate, the cam releases the trip bar a second time, thus operating the transmitter cam again and allowing the combination bars to set back against a second ward on the answer back drum. This operation is repeated for every ward on the drum until it is again arrested by its detent.

It is obvious that every answer back device must be able to send out a different series of letters and figures corresponding to the code or number of the station. The wards on the answer back device are therefore mounted in such a way that they can be readily changed by the mechanic when the machine is installed. By undoing two screws, the washer which holds these wards in place can be removed. The wards then simply slide out and can be replaced by new ones.

The Automatic Starting and Stopping Switch.

In order that the teleprinter may be left unattended, it is fitted with an automatic switch which completes the motor circuit immediately the printer electromagnet is operated. If an interval of about one and a half minutes elapses without any signals being received, the switch automatically breaks the motor circuit again, thus permitting the motor to run only during the periods in which messages are being sent.

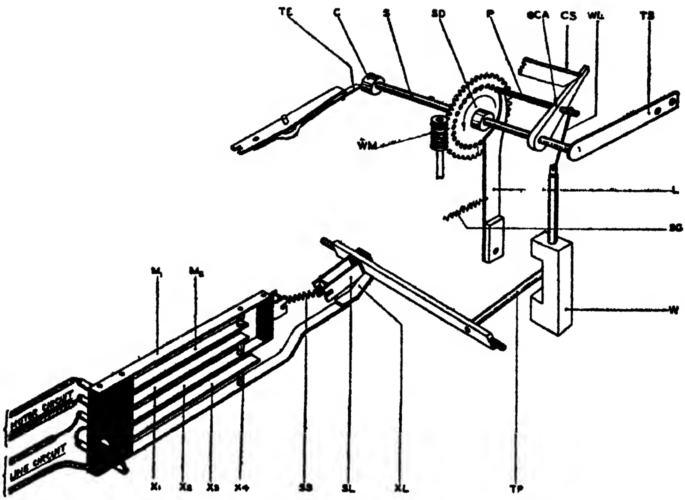


FIG. 57.—ILLUSTRATING THF ACTION OF THE AUTOMATIC START AND STOP SWITCH.

Fig. 57 shows the essential parts of the switch and its operating mechanism in the position which they occupy when the machine is at rest.

When the first starting impulse is received, the relay armature extension *TE* is thrust against the boss and moves the shaft *S* in the direction of its axis, thus disengaging pin *P* from the hole in disc *SD* and permitting the weight *W* to fall. When the weight *W* drops, it strikes lever *TP* and turns it about its pivot. This movement, operating through a toggle spring *SS* causes the switch operating blade to be thrust downwards, closing the motor control M_1 and M_2.

When no signals are being received the pin *P* remains engaged in disc *SD* and the weight *W* is slowly raised.

This in turn actuates lever *TP* and operates the contacts M_1 and M_2 which interrupt the motor circuit.

The Motor and Governor.

The motor may be either series, universal or shunt wound type. Shunt wound motors can be provided for operating from D.C. supplies lower than 40 volts where mains supplies are not available. The motor speed is 3,000 r.p.m., and this is maintained constant within $\pm$ 0·5 per cent ($\pm$ 15 r.p.m.) by means of a centrifugal-type governor mounted on an extension of the motor shaft. The action of the governor with increasing motor speed is to break or make a pair of electrical contacts. A *make* action may be used to short-circuit a resistor in the field circuit of a D.C. shunt motor and a *break* action may be used to remove a short circuit from a resistor and insert it in series with the armature of either a series or shunt D.C. motor.

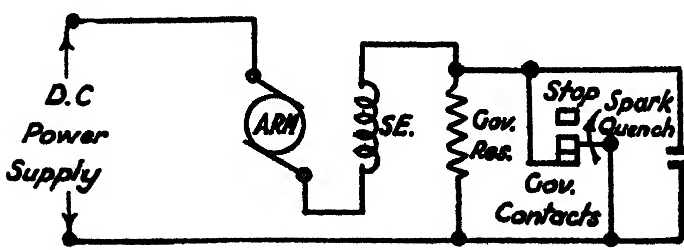


FIG. 58.—METHOD OF SPEED CONTROL OF TELEPRINTER MOTOR.

The arrangement for governing the DTN type teleprinter (7B) is shown in Fig. 58. An increase of speed above normal, causes the governor contacts to open, causing a resistance to be inserted in the motor circuit, thus reducing the voltage applied to the motor. The

speed of the motor falls until a speed is reached when the governor contacts make, after which the speed of the motor will increase consequent upon the increased armature voltage. As the inertia of the governor arm is in each case small, it is quick to follow speed variations, and by its continual rapid oscillation keeps the speed governed within close limits. The teleprinter motor is driven from 110 volts D.C. supply.

The teleprinter		No. 3	has a	shunt	wound	motor
,,	,,	No. 7A	,,	,,	,,	,,
,,	,,	No. 7B	,,	series	,,	,,

When A.C. power is available, a rectifier unit is employed to convert to D.C. for operating the motor of a teleprinter and also for supplying the line-signalling current. A typical arrangement is shown in Figs. 54 and 59.

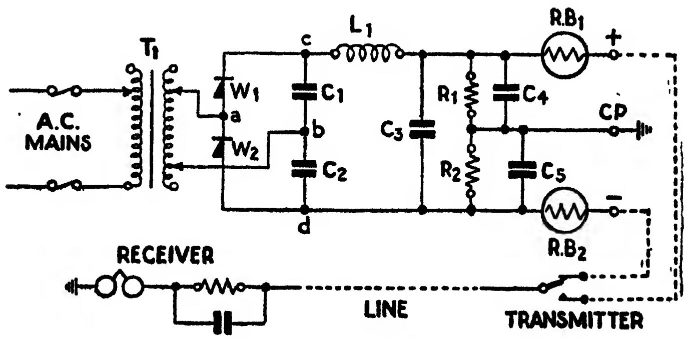


FIG. 59.—ILLUSTRATING THE GENERAL METHOD OF RECTIFICATION.

The A.C. main supply is connected to the primary winding of the transformer T_1, the correct tapping being selected for the voltage involved. The secondary winding is also provided with tappings to enable the output voltage of the unit to be adjusted to the correct value.

The system of rectification employed is the *voltage doubler* arrangement, comprising two metal rectifiers, W_1 and W_2 and condensers C_1 and C_2. During half cycles of the supply voltage when point "*a*" is positive with respect to point "*b*", rectifier W_1 offers a low resistance path and current flows into condenser C_1 which becomes charged, so that point "*c*" is positive with respect to "*b*". Similarly, during the reverse half cycles of the supply voltage, rectifier W_2 offers a low resistance path and condenser C_2 becomes charged so that point "*b*" is positive with respect to point "*d*". Under no-load conditions condensers C_1 and C_2 are each maintained charged to the secondary voltage of the transformer, and the total voltage between "*c*" and "*d*" is equal to twice this value.

When a load is applied, condensers C_1 and C_2 supply current to the load circuit, each condenser becoming partially discharged during the half cycles of supply voltage when its corresponding rectifier is not conducting and becoming re-charged during the half cycles when the rectifier is conducting. By suitable choice of component values in relation to the load to be supplied, the unsmoothed rectified voltage can be maintained at a value approximately twice that of the secondary R.M.S. voltage.

The choke L_1 and condenser C_3 form a filter to suppress the A.C. component of the rectified current to ensure that the effects of ripple currents shall not interfere with the performance of the telegraph relays to be supplied by the rectifier. Resistors R_1 and R_2 serve the dual purpose of providing a centre point earth connection on the output of the rectifier and of imposing a minimum load on the rectifier, thereby improving its effective regulation. Condensers C_4 and C_5 are provided to

give the rectifier unit a low dynamic impedance, and the resistor bulbs RB_1 and RB_2 are of a type which limits the fault current which can be drawn from the rectifier to a safe value.

The rectifier described was designed to provide a signalling supply equivalent to that obtained from a low impedance battery source, the arrangement of the output circuit being one of the principal factors contributing to this. The normal load is approximately 4,000 ohms D.C. resistance, and the output of the rectifier is adjusted for service by the transformer secondary tappings, with this value of load connected between the centre point and one side of the output. The correct voltage measured across the load is 80 volts (equivalent to 20 mA. into 4,000 ohms). The voltage across the unloaded side of the output will at the same time be approximately 120 volts.

Under working conditions the load is connected alternately across either side of the rectifier output, and during each signal element the output shunt condenser on the unloaded side charges to this high voltage (120 volts). This ensures a rapid build-up of current into the line and receiving apparatus at the commencement of each signal element, and produces a signal comparable with that obtained from an 80 volt battery.

The Standard Teleprinter Table.

A metal teleprinter table is usually associated with the teleprinter and in this case accommodation is available underneath the table for fixing the rectifier unit and associated equipment. Fig. 60 shows the usual installation of teleprinter and table. The dimensions of the teleprinter table are 3 ft. by 2 ft. 6 in. and 2 ft. 3 in. high.

FIG. 60.—THE STANDARD METAL TELEPRINTER TABLE WITH TELEPRINTER.

Teleprinter Covers.

To prevent the ingress of dust into the mechanism of the teleprinter it is normally fitted with a dust cover, but in circumstances where quietness is of considerable importance, the machine may be fitted with a special silencing cover instead of a dust cover.

Dimensions and Weights of Teleprinters.

The overall dimensions of the teleprinter including its dust cover are, width 19½ in., height 10½ in., depth 23½ in. Its weight is approximately 66 lb.

The Teleprinter No. 3

The main principles of operation of the teleprinter No. 3, used by the British Post Office for Inland Telegraph purposes, are similar to those of teleprinter No. 7. The teleprinter No. 3 does, however, differ mechanically from No. 7 teleprinter, as will be seen from the Table given below.

	7B TELEPRINTER	3A TELEPRINTER
SPEEDS	Motor Shaft 3,000 r.p.m. Receiving Cam 461.5 r.p.m Transmitting Shaft 400 r.p.m. Type-Wheel Spindle 642.9 r.p.m	2,520 r.p.m. 420 r.p.m. 392 r.p.m. 630 r.p.m.
TRANSMITTER	Operates at 50 bauds (International Speed).	Operates at 49 bauds
RECEIVER	Can receive 7 or 7½ unit Code	Receives only 7½ unit Code
KEYBOARD	International Keyboard. Spacebar common to both types. Figure and Letter Shift operated by separate keys. (Mixed groups can be signalled without space.)	Specially adapted for P.O. use. Shift operated by Spacebars marked Figs. and Ltrs. respectively. (Change-over therefore always includes a space.)
PRINTING	Page or Tape attachment. (Multicopies.) Visual record of transmission.	Tape only. Invisible correction of errors.
IMPRESSION	Typewriter ribbon	Ink-rollers (changed daily).
MOTOR CONTROL	After 90 secs. idle motor automatically switched off. Receiver re-started by first armature movement, i.e. receipt of start signal. Transmitter re-started by push-button on side of instrument.	Motor continuously running. (No automatic motor switch fitted.)
AVAILABILITY	Generally Simplex (local record).	Duplex or Simplex.
FUNCTIONAL LATCHES (Used on 7B only.)	1. A/B (Drum fitted with 20 wards cut to combination required.) 2. Carriage Return 3. Line Feed. 4. J. Bell (To attract attention). 5. Letter Shift (Paper movement inoperative). 6. Figure Shift (Paper movement inoperative).	A/B operates on depression of (Fig. D) " Who are you " key. Only method of call is continuous Transmission of code for required station. Depression of all keys operates space.

The Teletypewriter

The Teletypewriter is an American-produced machine which performs the same function as the British Teleprinter, i.e. transmits and receives messages in the form of typescript over landlines or radio links.

Both machines use the *start-stop* five-unit code, and with a suitable adapter unit a teleprinter can be made to transmit and receive messages from a teletypewriter. The machine made its first appearance in large numbers in this country in 1943. The use of an adapter when working teleprinter to teletypewriter or working two teletypewriters over a voice frequency telegraph system is necessary because the teletypewriter transmits single current signals as opposed to the double current signals of a teleprinter.

In addition, multi-channel voice frequency telegraph systems (by which the vast majority of long-distance telegraph circuits are routed in this country) use static relays and therefore require double current signals, see page 17. The main function of the adapter is to convert single current signals received from the teletypewriter into double current signals and thus operate the V.F. equipment and distant printer. The receiving mechanism of the teletypewriter will operate correctly on the reception of either double current or single current signals.

The teletypewriter can be fitted in addition to the direct keyboard transmitter, a tape perforator and auto-transmitter in much the same way as the Creed teleprinter. Thus an operator whilst transmitting signals to a distant station, also perforates a tape, then any further transmission of the message can be made by means of the automatic transmitter.

CHAPTER III

THE TELEPRINTER SWITCHBOARD

A LARGE numbei of teleprinter switchboards have been installed throughout Great Britain in recent years.

The function of a teleprinter switchboard is similar to that of a telephone switchboard, but with teleprinters replacing telephones, and any conversations or messages being teleprinted. Facilities are provided on all teleprinter switchboards to enable any station to transmit simultaneously, or *broadcast*, a message to a group of stations also connected to that switchboard.

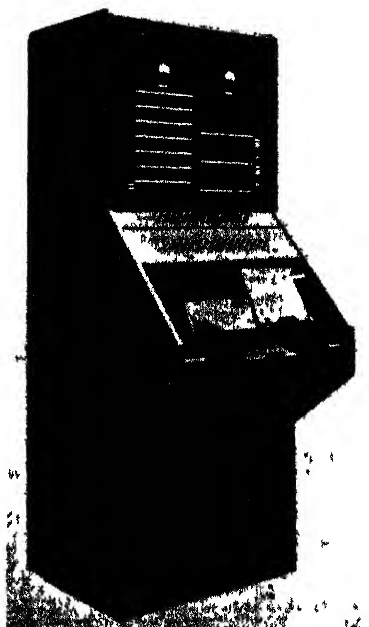


FIG. 61.—A SINGLE POSITION NO. 8 SWITCHBOARD.

Switchboard Layout (Single Position).

The switchboard circuits are terminated on jacks fitted in the

front of the board, Fig. 61. Immediately above the jacks are the calling lamps (white) and engaged lamps (red). Thus each circuit possesses one jack and two lamps. A designation strip (upon which the codes of the stations are engraved) is fitted immediately above the lamp strip to give guidance to the operator. The plug and keyshelf consists of a number of calling and answering plugs with their associated supervisory lamp and *print and monitor* keys. One print and monitor key is associated with each pair of cords, and each keyboard position is fitted with one call and answer key. The switchboard No. 8 is fitted with fifteen pairs of cords per position (see Fig. 61), while the switchboard No. 13 is fitted with ten pairs. With some types of switchboards, such as Nos. 8 and 9, the operator's teleprinter is housed on the switchboard immediately below the keyshelf, while with the switchboard No. 13 and smaller types, a separate table is fitted at right angles close to the switchboard.

The broadcast lamps, jacks and keys occupy the front right-hand side of the switchboards Nos. 8 and 13. When connecting lines to a teleprinter switchboard a point to be borne in mind is the ratio of lines connected to the number of cords. For instance, a No. 8 board will accommodate seventy lines, but as there are only fifteen pairs of cords, it would be ridiculous (unless the stations connected had a very low calling rate) to place seventy stations on the switchboard, as with all cords in use only thirty of the seventy stations could be working. To overcome this difficulty a second or even a third No. 8 board can be joined in ancillary, this allows two or three operators positions according to the number of boards used and gives a similar multiple of cords. Such arrangement is limited to a maximum of 100 lines.

Teleprinter Switchboard No. 9.

For the large switching centres a slightly different type of switchboard is used, known as the No. 9 type. This is a multiple board and any number can be joined together so that the load is distributed along the entire switchboard. The largest switchboard of this type installed in this country so far has twenty-four positions, and up to 500 lines can be connected. Each switchboard position is divided down the middle and so forms two panels on every board, see Fig. 63. The lines connected are arranged on what is termed either a 3-panel or a 4-panel multiple. This means that all stations connected to the switchboard are contained in either 3 or 4 panels, so that one-and-a-half or two positions contain every connection on the switchboard (see Figs. 63 and 64).

This arrangement is repeated, or multiplied along the entire

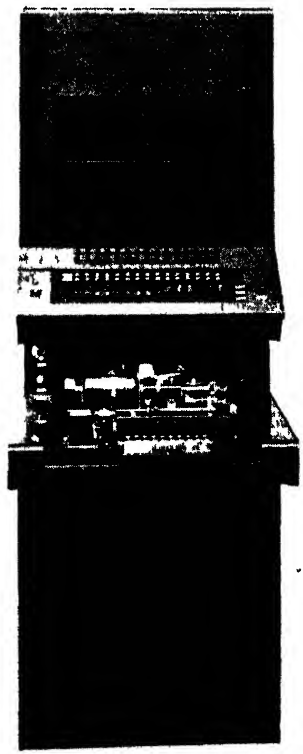


FIG. 62.—THE SWITCHBOARD NO. 9.

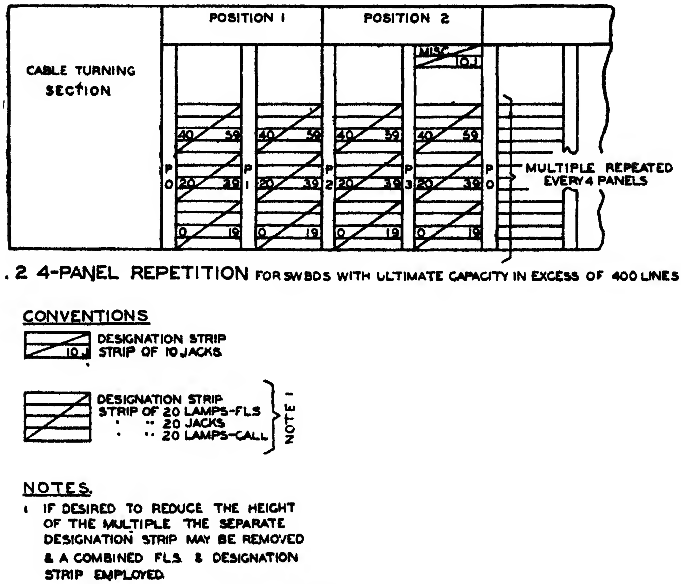


FIG. 63.

board, i.e. if it is a 4-panel multiple and there are eight positions, the stations appear four times along the entire switchboard. The cords are long enough to

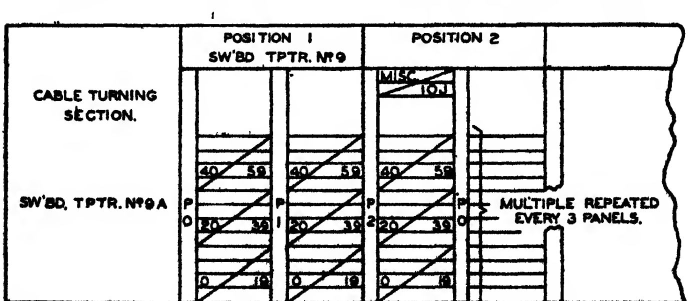


FIG. 64.

allow an operator to answer all calls on the position at which she is sitting and also one panel—which is half a position—on either side. Thus on an eight-position board eight operators can answer any call. A *duplicate connection* lamp is fitted on the left-hand side of each position so that if two or more operators answer the same call this lamp flashes on the position last to answer the call, but does not affect the position which answered first. On the position where the operator receives this *duplicate connection* light the cord is withdrawn and a button immediately below the light is pressed which resets it for future eventualities. The red *engaged* lamp which is fitted on single boards, or No. 8 boards in tandem, is dispensed with and what is known as a *free line signalling light* is substituted. This light appears immediately above the calling light and is screened by means of a celluloid strip so that only a glow about four times the size of a pinhead is showing. When the line is engaged this light is extinguished and so indicates to other operators that the line is engaged. Where a station has more than one line connected to the switchboard the *free line* signal travels along and appears over the first free line. When all the lines to that particular station are engaged no light glows, the operators can then see immediately that all lines are engaged.

For broadcast purposes a separate panel (switchboard No. 14) is provided and generally worked in conjunction with the first position on the switchboard. This panel is provided with a series of keys and lamps according to the number of stations requiring broadcast facilities. These stations are specifically named and each key is labelled with the code of that particular station. By throwing a key on the broadcast panel the station associated

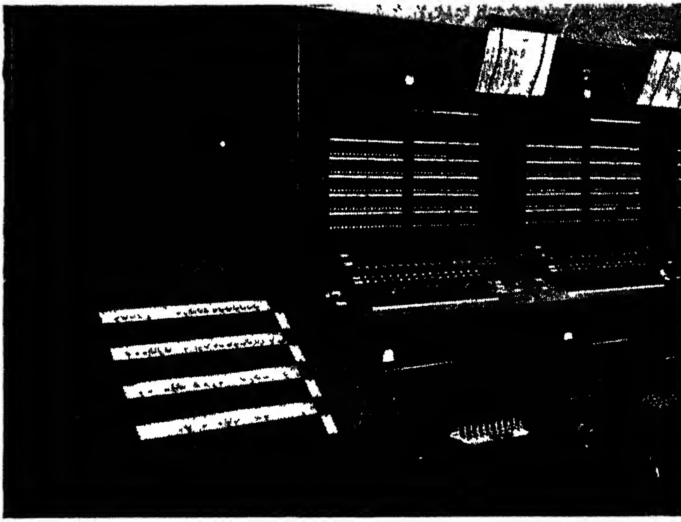


FIG. 65.—A BROADCAST SWITCHBOARD NO. 14, AND THE FIRST TWO POSITIONS OF A NO. 9 SWITCHBOARD INSTALLATION.

with that particular key is brought into the jack field on the switchboard. At the same time it causes an engaged condition to appear over that station's position along the entire switchboard, the free line signal light going out. When all the stations required for the broadcast have been *collected*—all the keys on the broadcast panel being thrown—the operator inserts the calling cord into the broadcast jack and the answering cord into the station requiring the broadcast, teleprints *K Your Broadcast* to whatever station required and restores the print and monitor key. When the station sending the broadcast message has finished transmitting, the answer back, or clear key is raised for five seconds, which when released gives a clearing light on the switchboard; the operator then goes into circuit and gives the

transmitting operator each of the stations in turn for *R* (message received satisfactorily).

Details of Teleprinter Switchboards.

SWITCHBOARD No. 8 (Fig. 61). This switchboard provides intercommunication facilities for seventy lines, including extension teleprinters, together with broadcasting facilities. Any line may broadcast—but only twenty selected lines may receive broadcasts. A second switchboard may be worked in ancillary if required. The dimensions of the switchboard are 6 ft. 6 in. high, 2 ft. 6 in. wide, 3 ft. 3 in. depth across the keys. Associated with the switchboard is a panel 10 ft. 6 in. or two panels 5 ft. 3 in. high.

SWITCHBOARD No. 9. This switchboard is for large installations and provides intercommunication facilities only. Any capacity can be designed — at present 200, 300, and 500 line types are in use, and

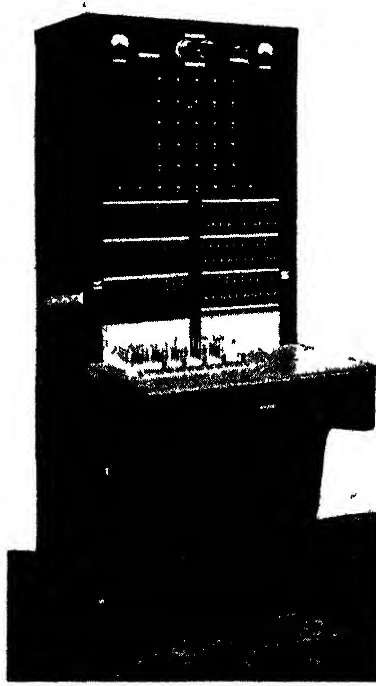


FIG. 66.—THE TELEPRINTER SWITCHBOARD No. 13.

any number of operator's positions may be provided in ancillary. Free-line signalling is provided. A switchboard No. 14 can be associated with the switchboard for broadcasting facilities if required. Any line may broadcast but only forty selected lines may receive the broadcasts. Dimensions as for switchboard No. 8.

SWITCHBOARD No. 13 (Fig. 66). Facilities are similar to those of switchboard No. 8, but is designed for thirty lines and broadcast. All lines may originate and receive broadcast messages. Dimensions, 5 ft. 6 in. high, 2 ft. 6 in. depth across keys. The switchboard is entirely self-contained.

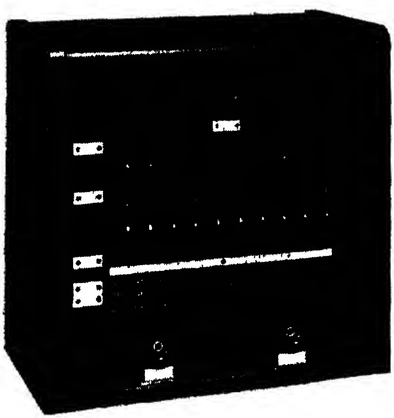


FIG. 67.—THE TELEPRINTER SWITCHBOARD No. 15.

SWITCHBOARD No. 15. This is a ten-line switchboard providing intercommunication and broadcast facilities. Any line may send or receive a broadcast message.

SWITCHBOARD No. 16. This is a concentrator unit: it provides concentration facilities for fifteen outgoing and fifteen incoming lines to fifteen local extension teleprinters and permits two simultaneous broadcasts. It is similar in general appearance and size to switchboard No. 13.

Methods of Connecting Teleprinters.

The various methods of connecting teleprinters are shown in Fig. 68. With a point-to-point simplex teleprinter circuit the two teleprinters are directly connected to one another as shown (1). Each teleprinter transmits on one line and receives on the other. The junction

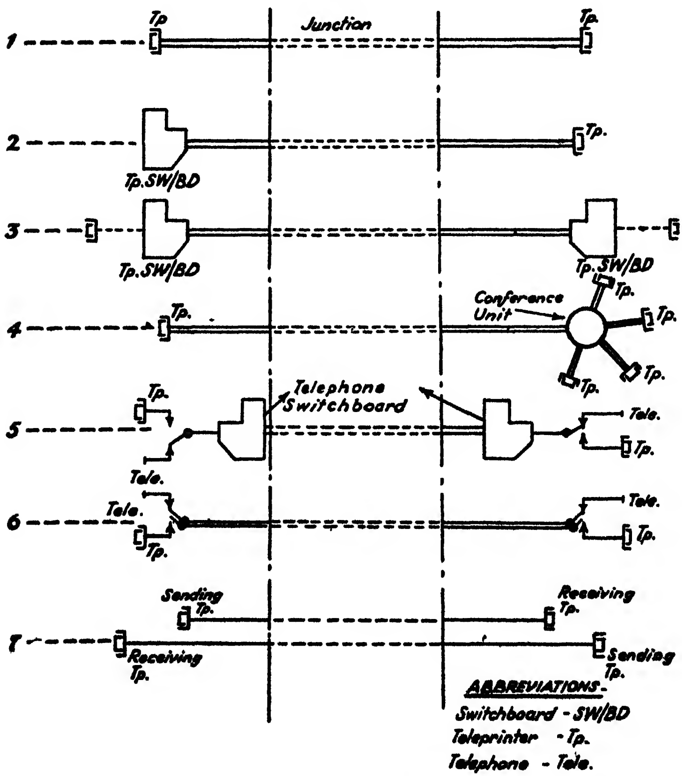


FIG. 68.—ILLUSTRATING VARIOUS METHODS OF CONNECTING TELEPRINTERS.

connecting the two teleprinters may consist of either a physical pair of wires or voice frequency channels; (2) shows a teleprinter connection to a teleprinter switchboard. The incoming and outgoing calls to and from the teleprinter will be passed via the teleprinter switchboard operator. The teleprinter in addition to having access to any other teleprinter on the switchboard as shown in (3) can have access to any circuit in the general teleprinter network. With the conference unit shown in (4), any one teleprinter can transmit and the other teleprinters connected to the conference unit receive the transmitted message. With the Telex arrangement (5) the call is originated by telephone via the telephone switchboards to the distant station. When connection is established communication can be either by telephone or teleprinter. A direct teleprinter telephone circuit (6) is similar to (1) but provides alternative teleprinter or telephone communication; (5) and (6) are known as public D circuits and the junction must be a physical circuit.

Two-way simplex or duplex working enables simultaneous transmission in opposite directions, with the result that a greater number of messages can be handled over a single circuit. One disadvantage with this type of circuit is that no *answer back* facilities are available.

To Establish a Call from One Station to Another Station on the Same Switchboard (DTN Method).

The calling station taps rhythmically on the space bar of the teleprinter; this causes the calling light to flash on the switchboard. The operator at the switchboard inserts any answering cord into the jack associated with

the calling light, at the same time bringing the *print and monitor* key down and the *call and answer* key forward; this brings the operator's teleprinter at the switchboard into circuit with the calling station's teleprinter, and the switchboard operator types the code of the switchboard, say VIC. The calling station then asks for the station required, say VIC ADM. If ADM is free the switchboard operator inserts the *calling* cord into the ADM jack and prints K, after which the *print and monitor* key is replaced. The calling station is now connected direct to station ADM. To verify this, the calling station depresses the *who are you* key and immediately receives the answer back of the station ADM. The message is then transmitted.

At the end of the message, if it has been received satisfactorily, the letter *R* is transmitted. Upon receipt of *R* from ADM, if there is no further traffic to be passed, both stations hold up the *acknowledge* key associated with the teleprinters for 5 seconds. When the *acknowledge* key is released, the clearing, or cord circuit supervisory lamps on the switchboard light up, informing the switchboard operator that both stations have finished. The switchboard operator then removes both cords and both stations are then free to either receive incoming calls, or to call the switchboard again for outgoing calls.

Referring to the above procedure, had station ADM been already engaged the VIC switchboard operator would have teleprinted *ENGD* and the calling station would then either clear or request *book*, i.e. when the ADM line became free the connection would be established. Upon receipt of the clearing signal the switchboard operator removes the answering cord.

When a call has to be routed through two or more switchboards the operation is as follows:

Say ONO, a station on VIC switchboard, requires connection to RNP which is a circuit on PTM switchboard. ONO taps the space bar of his teleprinter, causing the calling light on VIC switchboard to flash. VIC operator inserts the answering cord into ONO's jack, thereby bringing into circuit the teleprinter at VIC switchboard, at the same time the VIC operator types *VIC*, indicating to ONO that VIC operator is in attendance. ONO then teleprints *PTM RNP* which is the call sign of the required terminal switchboard, and the station off that switchboard. If a junction between VIC and PTM is free the VIC operator inserts the corresponding calling cord into the free PTM junction and teleprints *THRU* and goes out of circuit, that is, restores the print and monitor key. ONO is now connected direct to PTM switchboard and proceeds to tap on his space bar, thereby flashing the calling light on the PTM switchboard associated with the VIC PTM junction. The operator at PTM switchboard inserts the *answering* cord into the VIC PTM junction and teleprints PTM, which. is received on the teleprinter at ONO. ONO in turn teleprints *PTM RNP*. If RNP is free the PTM operator connects the call, teleprints *K*, and goes out of circuit. ONO depresses his *who are you* key which operates the *answer back* unit at RNP, and ONO receives RNP on his teleprinter. The message is then transmitted.

When traffic has been cleared both RNP and ONO hold their respective *acknowledge* keys up for five seconds, which, when released, light the clearing lamps at both PTM and VIC switchboards. Both switchboard operators remove the respective cords, thus restoring ONO

and RNP to normal conditions. If, after asking PTM for RNP, PTM teleprints *ENGD* (denoting engaged), ONO, not requiring any further tail off PTM raises his acknowledge, or clear key, and clears as above. PTM depresses the button on his switchboard which is marked *clear* and is equivalent of the acknowledge key on a teleprinter, and VIC switchboard receives both clearing lights. VIC operator removes both cords, thereby restoring both ONO and the VIC PTM junction to normal conditions. In the above example ONO on receiving *ENGD* for RNP could ask the PTM operator for T/P guard.

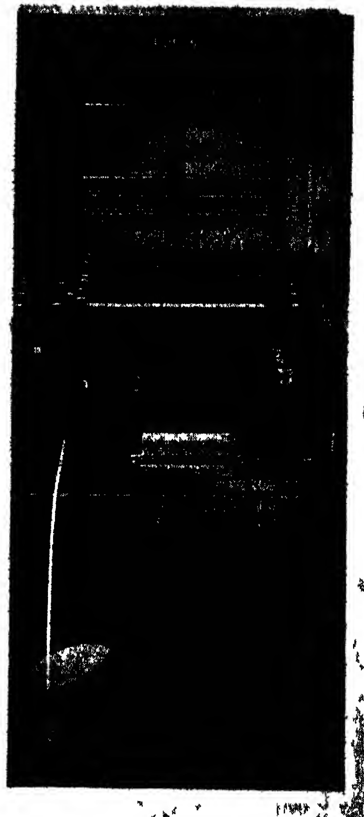


FIG. 69.

Function of T/P Guard.

On some large teleprinter switchboards a selected number of teleprinters, usually in an adjacent room, are

connected to that switchboard and are known as T/P guard machines.

The function of the T/P guard is to accept messages from distant calling stations who have found the called station on the main switchboard engaged. The guard machines have operators in attendance, and after receiving the message the T/P guard operator gives the usual acknowledgment and the connection is cleared down. Later, when required the station becomes free, the T/P guard operator retransmits the message to the station.

To quote the previous example the precise procedure is as follows: ONO having been connected to PTM switchboard for PTM, RNP, and receiving *ENGD* to the request for RNP, then prints T/P guard. If a T/P guard machine is free ONO is connected, the PTM operator prints *K* and goes out of the circuit. ONO then passes the message to the T/P guard teleprinter instead of direct to RNP, and at the end of the message the T/P guard operator prints *R* (received). The provision of a T/P guard system reduces waste of line time on the main junctions as, without this facility, ONO might have to try several times before finally establishing connection with RNP. Each unsuccessful attempt means additional work for the switchboard operator and wastage of line time. Furthermore the T/P guard can book a call for any *tail* on its own switchboard, whereas ONO coming through a switchboard junction cannot book. Booking of calls on switchboards is restricted to stations on the home switchboard.

Use of Automatic Equipment.

Some T/P guard rooms are fitted with Teleprinter automatic equipment consisting of:

A Teleprinter Reperforator.
A Teleprinter Auto-Transmitter.
A Teleprinter Perforator.

This equipment is shown at the right-hand end of the bench in Fig. 70.

In the above example ONO, instead of being connected to a T/P guard teleprinter, could have been

FIG 70 —THE TELEPRINTER GUARD ROOM OF A LARGE SERVICES SWITCHING CENTRE

connected to a T/P guard reperforator. When so connected his transmitted signals cause a thin paper tape to be perforated. An example of this tape is shown in Fig. 71. Later, when RNP becomes free, connection is established from RNP to the automatic transmitter in the guard room and the perforated tape is fed through the auto-transmitter which transmits the signals to

operate RNP's teleprinter at maximum speed, i.e. 66 words per minute.

Traffic is thereby effectively dispatched from the teleprinter guard room with the minimum of delay.

The Public Inland Telegraph System.

The Military Services were the first to adopt the teleprinter switchboard principle of through switching. It was not until the concluding stages of the Second World War that the G.P.O. commenced installing teleprinter switchboards for the public inland telegraph system. At this stage the D.T.N. had grown to enormous proportions and was approximately three times greater than the public inland telegraph network of this country. The earliest switchboards installed for the public services were at Leeds, Manchester and Birmingham and a slightly different calling and routing procedure was adopted to that employed in the D.T.N.

Establishment of a Connection (Inland Telegraph Method).

To originate a call the transmitting operator signals the code of the desired office by depression of the appropriate keys of her teleprinter, e.g. DON. Depression of the keybars operates a calling switchboard relay and an associated calling lamp lights. The switchboard operator inserts an answering plug into the associated line jack and moves the cord key to the answering position. She then operates her print and monitor key and observes the incoming signals, i.e., the answer-back-code of the desired station—DON. If the required station is free she inserts the associated calling cord in the line jack of the desired station, prints the letters D.F.—which

indicates to the caller that connection has been established with the station, then she restores her cord key and print and monitor key to normal.

The originator of the call is now connected to the station whose answer back code he has been calling, immediately therefore, he receives D.F. he depresses the figure-shift key of his teleprinter, followed by the "who-are-you" key and thereby receives the answer back of the station to whom he is connected.

Upon verification of satisfactory connection the calling operator proceeds to transmit messages. The answer back code of the distant station is obtained at the end of the message to verify that no disconnection has occurred.

To clear down the connection both stations operate their clearing keys in a manner similar to the D.T.N. method.

Through Switching (Future Developments).

One development of the future which the British Post Office have in mind is to convert manual switchboard working to automatic working. Connection to a distant station will be achieved by dialling as in automatic telephony.

CHAPTER IV

TELEGRAPH FIVE-UNIT CODE AUTOMATIC EQUIPMENT

Automatic Tape Transmission.

GENERALLY speaking teleprinter systems with automatic tape transmission are used where the traffic per channel is too great for direct keyboard transmission. With automatic transmission it is possible to keep the transmitting and receiving apparatus in operation without the stoppages that are unavoidable with direct keyboard operation, due to checking messages and transcribing badly-written words.

Instead of transmitting the signals direct to the line as each key is depressed, the operator prepares the messages in the form of perforations in a paper tape.

Two methods of preparing this tape can be employed:

(*a*) A perforating attachment can be fitted to the keyboard transmitter and facilities thus provided for simultaneous keyboard transmission and tape preparation or for either operation independently.

(*b*) A separate keyboard perforator can be provided with a keyboard similar to that of the teleprinter but without direct transmission facilities.

The prepared tape is then fed through an instrument called an automatic tape transmitter, which transmits the message to the line in accordance with the perforations in the tape.

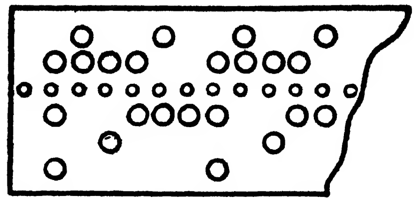


FIG. 71.—A PORTION OF 5-UNIT TAPE.

This automatic transmitter can either be provided as a separate machine or mounted on the same base and driven by the same motor as the keyboard perforator described in (*b*) above. In this way it is possible to keep the line fully occupied, the only requirement being that the operator must maintain a short loop of tape between the keyboard perforator and the transmitter.

Due to the absence of any locking bars, experienced personnel should be able to perforate simple text at a speed of say 80 words per minute and reduce speed when perforating difficult words, code and figure groups. The operator may also stop occasionally to sign and time messages, but as the keyboard is entirely *free* there is no restriction of his or her speed and as long as the loop of tape between the keyboard and the automatic transmitter is kept slack, the regular flow of traffic over the line will be unaffected.

A special device avoids the possibility of the tape being torn or mutilated in the event of the operator stopping for too long a period. The tape passes below a light switch-arm extension and just before it becomes taut it raises this arm and so stops the transmitter until the tape is again slackened by the operator resuming work.

Two or more operators can be utilised to prepare tape for one automatic transmitter, this arrangement being particularly advantageous at stations where *Immediate*

ordinary and deferred traffic alternates frequently, or alternatively where long and very short messages have to be transmitted.

Principle of the Automatic Transmitter.

Fig. 72 illustrates the principle of one simple form of morse automatic transmitter. The prepared paper tape is fed through the transmitter by means of the star wheel *SW*; a lever pivoted to lie in a horizontal plane has a point at one end, which rests lightly on the paper tape due to

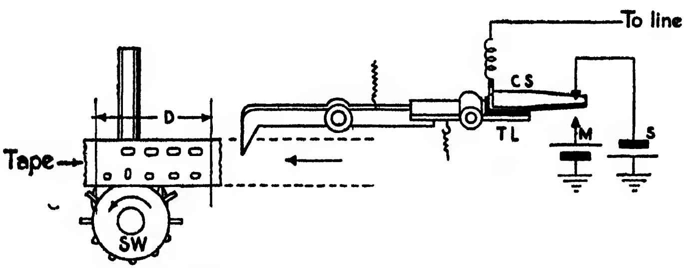


FIG. 72.—ILLUSTRATING THE PRINCIPLE OF A SIMPLE AUTO-TRANSMITTER.

the action of a light spring pulling the other end in an upward direction. When a hole in the paper appears under the pointed end of the lever the point drops into it; the other end of the lever tilts a transmitting lever *TL* to which is attached a contact lever *CS*. This lever or tongue is capable of movement between two battery contacts *S* and *M*, depending upon whether the point of the horizontal lever is riding on the paper or projecting through a hole. In this manner the corresponding signals are sent to line. The contact tongue is restored to the upper contact by a light spring attached to the underside of the left-hand of the lever *TL*.

The Teleprinter Automatic Tape Transmitter.

This unit is associated with the keyboard perforator where teleprinter working is upon an automatic tape transmission basis. Its function is to translate the five-unit code combinations perforated in the tape into the corresponding current combinations and to transmit these currents to the line.

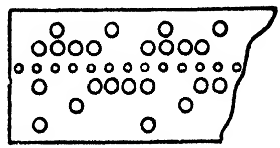


FIG. 73.

It consists of two main parts: a framework carrying the driving motor, and the transmitting mechanism which is mounted in a unit called the transmitter head, see Figs. 74 and 75.

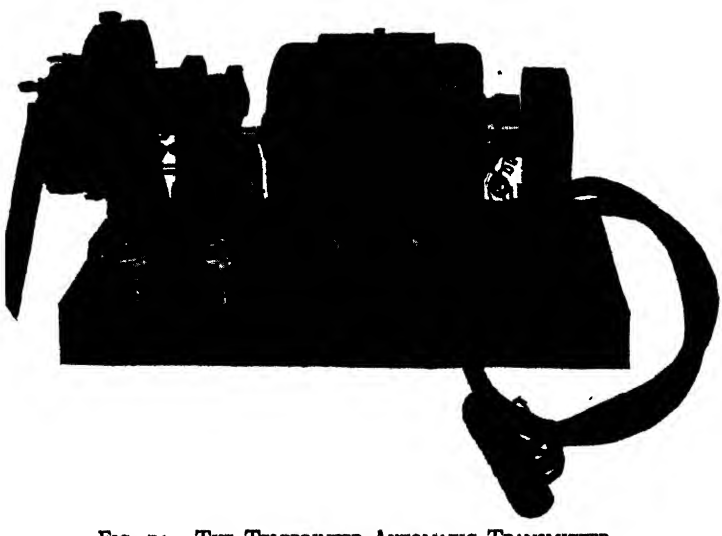


FIG. 74.—THE TELEPRINTER AUTOMATIC TRANSMITTER.

Operation.

The perforated tape passes over a platform on the front of the transmitter head and it is fed forward at a uniform speed by a sprocket-wheel *L* which engages the small feed-holes in the tape. The tape can be of two types:

(*a*) With the centre line of the feed-holes in line with the centre line of the signal-holes; or

(*b*) with the feed-holes slightly in advance of the signal-holes (see Fig. 73).

Care should be taken that the starting end of the tape is inserted into the transmitter. With type (*a*) this can only be determined by reading the commencing letters

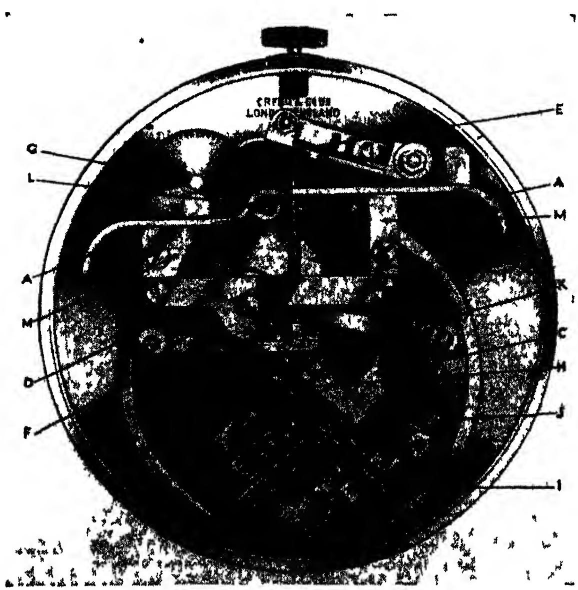


FIG. 75.—THE TRANSMITTING HEAD.

or by the operator marking the front end. With type (*b*) the direction of the tape should be as shown in Fig. 73, the feed-holes slightly leading the signal-holes.

Five of the six selecting levers *F* which pass under the cam, carry peckers at their right-hand ends. These levers are pivoted at their left-hand ends, and are held against the cam by the upward pull of their springs When the cam rotates, each lever in turn is released for the duration of one signal impulse, and is free to rise under the control of the perforations in the tape.

The free ends of the selecting levers extend under the upper arm of the contact arm operating lever *C*. The lower arm of this lever has a forked end between the prongs of which is the insulated portion of the contact arm J. The operating lever *C* is pivoted at its apex, and has a spring attached which pulls it downwards and presses the contact arm against the spacing contact *I*. When one of the peckers is allowed to rise, its associated lever *F* lifts the operating lever *C*, throwing the contact arm over to the marking side.

While tape is passing through the transmitter each lever will rise in turn, when allowed to do so by the cam, if there is not a perforated hole the lever will remain down; the pecker spring not being strong enough to cause the pecker to pierce the tape.

The pecker levers are allowed to rise successively in the following order: 3, 1, 2, 4, 5, 6, counting from the back. At the commencement of each signal, lever No. 3, which does not carry a pecker, is in the upward position, where it has set the contact arm to transmit the "stopping" impulse for the previous signal. The continued revolution of the cam sets this lever in the downward position and sends the *starting* impulse of the new signal.

Following this, levers 1, 2, 4, 5 and 6, each carrying a pecker, are allowed to rise in turn under the control of the perforations in the tape, sending the impulses which form the character. Lastly, lever No. 3 rises and, according to the last impulse retains or moves the contact arm over to the marking side. This sends the *stopping* impulse.

The peckers are staggered to an amount corresponding to the movement of the tape during the period occupied by the transmission of one signal impulse, and the holes in the pecker guide plate are slightly elongated so that the peckers can travel along a very short distance with the tape. A light spring holds the peckers against the front side of the holes in the guide plate.

A jockey roller, which rides on the knife edge of the

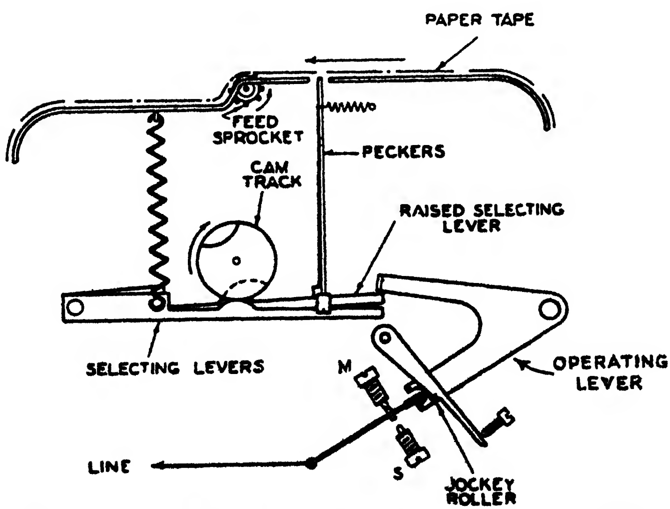


FIG. 76.—ILLUSTRATING THE PRINCIPLE OF OPERATION OF THE TELEPRINTER AUTOMATIC TRANSMITTER.

contact arm, holds the latter firmly against either contact, preventing it from moving from one contact to the other until a change of polarity is necessitated. This device also serves to shorten the transmit time.

SPEED OF OPERATION. The automatic transmitter must be set to operate at the same speed as the distant receiving printer(s). The apparatus is, therefore, normally adjusted to the standard speed of 50 bauds, i.e. 66 words per minute for 7½ unit transmission of 71 words per minute for seven-unit transmission.

PAPER TAPE. Parchment tape $\frac{11}{16}$ in. wide is used. This is supplied in rolls of about 950 ft. (approximately 19,000 words).

SPACE. The space occupied by the automatic transmitter is 15 in. × 8 in. × 8 in. high.

Tape Control Unit.

The tape is often fed direct from the keyboard perforator through the auto-transmitter, passing under the roller attached to the tape control lever (*F*) Fig. 77.

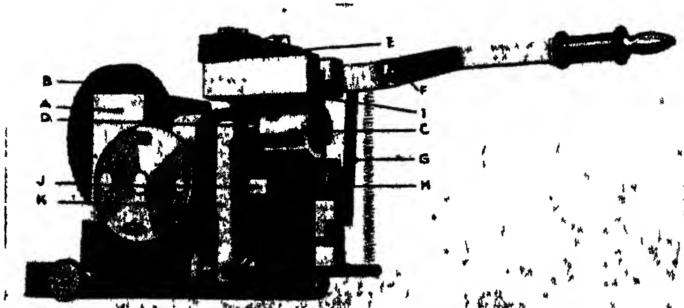


FIG. 77.—MECHANISM FOR SWITCHING OFF AUTO-TRANSMITTER WHEN TAPE BECOMES TAUT.

The tape control unit serves to declutch the transmitting head mechanism when the tape is drawn tight, owing to the auto-transmitter feeding the tape faster than it is being perforated by the operator. Mutilation of the tape is thus avoided. The unit is illustrated in Fig. 77, the principle of operation being shown in Fig. 78.

The large gear wheel (*B*) which may be seen at the back of the unit in Fig. 77, is constantly revolved by the driving motor, this motion being communicated to the transmitting head through the medium of the clutch mechanism, and the clutch sleeve (*C*).

As long as the keyboard perforator is being operated

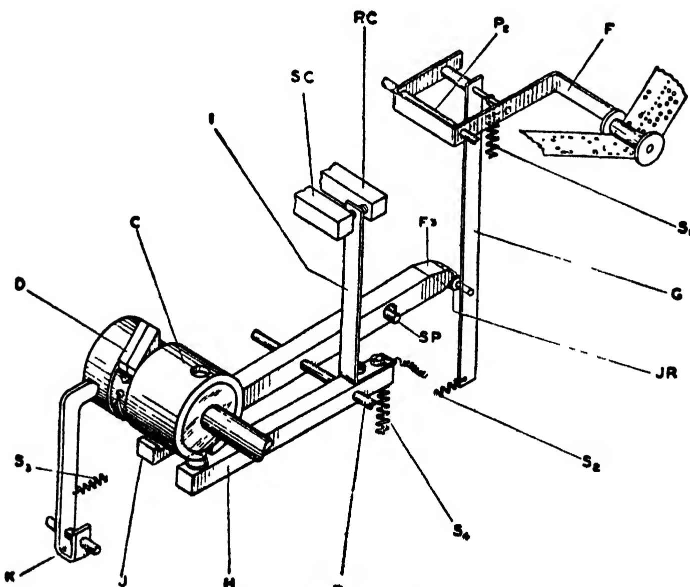


FIG. 78.—MECHANISM FOR SWITCHING OFF THE AUTOMATIC TRANSMITTER.

at a sufficiently high speed to keep the tape slack, the tape control lever is held down by the spring (*S*1), and the jockey roller (J*R*) attached to the lever (*G*), is pressed against the lower face of the detent lever (J) by the spring (*S*2). The detent lever (J) is free to move about the pivot (*P*1), the extent of its movement being restricted by the stop pin (*SP*); hence when the jockey roller is pressed against the lower face, the opposite end of the detent lever is held in its lower position. This permits the clutch mechanism to remain in engagement, and the transmitting head continues to operate until it overtakes the operator, and draws the tape tight.

When the tape is drawn tight the tape control lever (*F*) is turned about the pivot (*P*2), and lifts the lever (*G*) thus causing the jockey roller (J*R*) to ride over the end of the detent lever, and press against its upper face. This causes the opposite end of the detent lever to rise.

The Tape Control Clutch Mechanism.

The clutch sleeve (*C*) is normally coupled to the ratchet shaft (*SR*), Fig 79 by the pawl (*D*) which is held in engagement by the spring (*S*); but when the left-hand end of the detent lever is raised, the face (*F*1) of the pawl (*D*) comes into contact with the face (*F*2) of the detent lever (J). Thus the pawl is turned about its pivot, and disengaged from the ratchet. When the clutch sleeve (C) has been uncoupled from the ratchet shaft (*SR*), it is held stationary by the lever (*K*), which is held in engagement with a notch in the clutch sleeve by the spring (*S*3).

Immediately the tape becomes sufficiently slack the tape control lever (*F*), Fig. 78, drops and reverses the position of the detent lever. The pawl (*D*) is thus

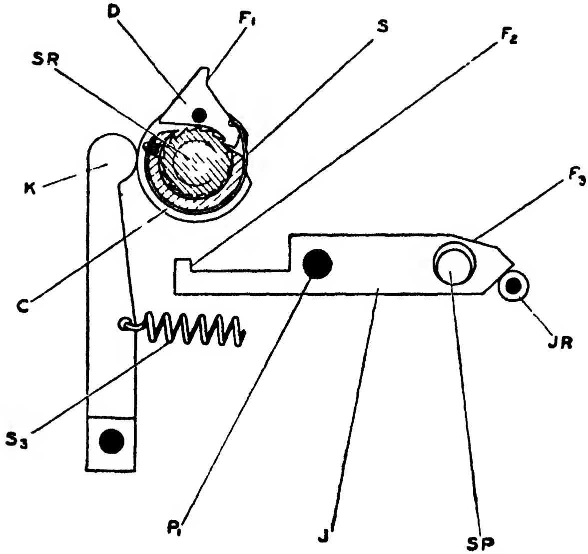


FIG. 79.—THE TAPE CONTROL UNIT CLUTCH MECHANISM.

allowed to re-engage, and the transmitting head resumes operation.

There are actually two pawls attached to the clutch sleeve, but as they operate in unison and engage with the same ratchet the above description is quite applicable to this arrangement.

On the same pivot as the detent lever, is a lever (*H*) made of an insulating material (see Fig. 78). This lever carries at one end a switch blade (*I*) which plays between two contacts (*SC*), (*RC*), and at the other end a hemispherical projection which rides on the periphery of the clutch sleeve (*C*). A hole cut in the clutch sleeve permits this projection to rise once during every revolution, and

causes the switch blade, which is normally against the contact (*SC*), to flick over to the contact (*RC*).

The pawls and the hole in the clutch sleeve are so placed that the driving spindle is not stopped, nor is the switch blade moved from the contact (*SC*) until the stopping impulse has been sent by the transmitter at the conclusion of a signal. When the clutch sleeve is brought to rest the switch blade is held against the contact (*RC*) by the spring (*S*4). This switch serves as an automatic send-receive switch.

It will be seen that the right-hand end of the detent lever (J) has cut on its upper surface, a third face (*F*3) with slightly less inclination than the faces on which the jockey roller normally operates. If the tape control lever is lifted by hand sufficiently high for the jockey roller to operate on this face, the spring (*S*2) will retain it in that position until it is manually reset. Thus an easy means of stopping the progress of the tape through the transmitter is provided; a facility which may be utilised when it is required to send an urgent message from the keyboard (if a transmitter unit is fitted) without disturbing the tape in the auto-transmitter.

Motor and Governor.

The teleprinter auto-transmitter is fitted with a 1/30 h.p. motor, the power consumption of which is 50 watts when connected to an A.C. supply, and 90 watts on a D.C. supply.

The Teleprinter Receiving Reperforator.

The teleprinter receiving reperforator is an instrument for translating the signals received from a teleprinter

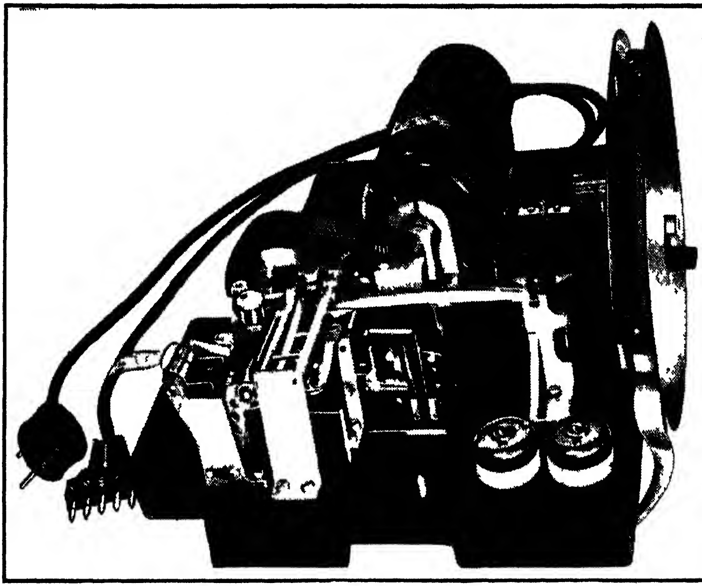


FIG 80.—THE TELEPRINTER RECEIVING REPERFORATOR.

keyboard or automatic tape transmitter into their equivalent perforations in a paper tape.

The selecting mechanism is similar in principle to that employed on the Teleprinter, the striker pin being arranged to control the operation of five punches. It will interpret correctly, signals either from seven-unit or seven-and-a-half-unit transmitters. The standard operating speed of the machine is 50 bauds, i.e. 66 words per minute.

The machine is a self-contained unit, being fitted with a driving motor which can be wound for any desired A.C. or D.C. supply between 100 and 250 volts and for any D.C. supply voltage down to 24 volts.

Two kinds of punching mechanism can be provided, one perforating the feed-hole centre in line with the signal-hole centres (centre line feed-hole) and the other providing for the front edges of the signal- and feed-holes to be in line (advanced feed-hole).

The tape is arranged to emerge from the machine in such a position that it can be fed directly into an automatic tape transmitter.

The general construction of the machine is shown in Fig. 80.

Operating Conditions.

The reperforator is normally arranged for double current operation, but parts may be fitted making it suitable for single current operation if required. The general conditions for operating Creed teleprinters also apply to the reperforator; that is, on a circuit where a teleprinter is normally used a reperforator may be substituted without alteration to the circuit arrangements. The operating magnet requires a minimum current of 20 milliamperes, which should be supplied from a battery of not less than 50–0–50 volts.

Automatic Motor Control. The machine is fitted with a unit which automatically starts the motor on receipt of the signal and stops it again at the termination of transmission if no signals are received during a period of approximately thirty seconds.

When the next signal is received the motor will automatically restart.

Speed of Operation. The reperforator must be set to operate at the same speed as the distant transmitter. The apparatus is, therefore, normally supplied for the standard teleprinter speed of 50 bauds (i.e. 66 words per

minute), but other speeds can be arranged for where required.

MONITORING. The receiving reperforator should be operated in conjunction with a receiving-only Teleprinter to provide a *local record*, or alternatively with a teleprinter transmitter-receiver if it is required to provide a *local record* and facilities for transmitting to the distant station.

PAPER TAPE. Parchment tape $\frac{11}{16}$ in. wide is used. This is supplied in rolls of about 950 ft. (approximately 19,000 words).

SPACE. The space occupied by the reperforator is 17 in. × 15½ in. × 10½ in. high.

Principles of Operation.

On receiving the starting (spacing) impulse the selecting mechanism is set in motion. As the five impulses representing the intelligence code are received, operation or non-operation of the five message punches is determined, and the tape punched. Following the five code

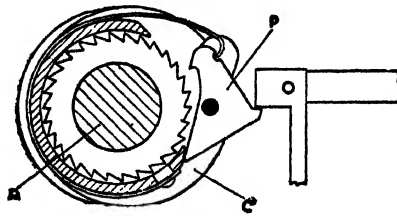


FIG. 81.
ONE REVOLUTION
CLUTCH MECHANISM.

impulses the stopping (marking) impulse is received and the mechanism is brought to rest.

The mechanism of the reperforator is controlled by a grooved cam which forms a sleeve, mounted on the driving shaft *R*. The cam is normally disengaged from

the shaft which rotates continuously. It is coupled to the shaft under the control of the received start signals by means of the *one revolution* clutch mechanism shown in Fig. 81.

The pawls *P* are mounted on a pivot in a slot cut in the cam wall in line with ratchets cut on the shaft *R*. When the cam is at rest the pawls are held out of engagement with the ratchets by a detent, Fig. 82.

On the receipt of a spacing signal the detent is withdrawn from the path of the pawls which rotate in an anti-clockwise direction under the action of a spring to enter into positive engagement with the ratchet teeth. The cam is then driven positively until, at the end of a revolution, the rear ends of the pawls strike the detent and are sharply rotated in a clockwise direction and disengage with the ratchets.

The pawl is held in the position of maximum disengagement by a retention lever *RT*, Fig. 82, which rests in a depression in the periphery of the cam and prevents any backward movement.

The receiving cam sleeve has four tracks which during each revolution perform the following functions.

Track No. 2 controls the position of the setting-pin *SP* so that at the centre of each successive signal element of the intelligence code it is passing the centre line of the corresponding hammer *H*.

When the cam is idle, the setting-pin *SP* rests opposite the third hammer. During the start impulse it moves into its first setting position behind hammer No. 1, after which, during reception of the five code impulses it passes at a uniform speed behind the remaining hammers and finally is restored to its idle position during the stop impulse.

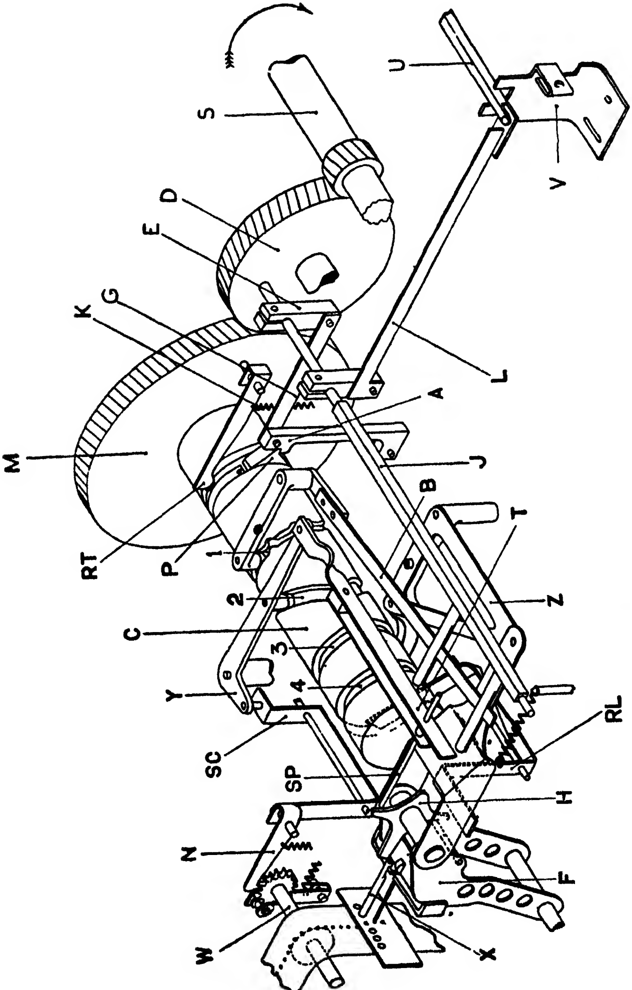


FIG. 82.—WORKING DIAGRAM OF A TELEPRINTER RECEIVING REPERFORATOR.

Track No. 1 causes the striker blade *B* to be moved towards the setting-pin *SP* five times during the reception of the intelligence code. The movement is timed to occur when the setting-pin *SP* is opposite the centre line of each of the five hammers *H* at the centre of each signal impulse. The striker blade *B* slides in guides secured to the trip shaft J, which is controlled by the operating magnet armature *U*. When the armature is in the marking position (to the left in Fig. 82), the striker blade *B* is in line with the setting-pin *SP*, and in being moved forward by the cam strikes the pin with the result that the hammer *H* is set downwards to the marking position. When the operating magnet armature is in the spacing position (to the right) the striker blade *B* is brought below the setting-pin *SP*, and when moved forward by the cam misses the pin, and the corresponding hammer *H* is left upwards in the spacing position. Thus, when the fifth signal element has been received, the five hammers are set in the marking or spacing positions corresponding to the intelligence code received.

When the positions of the five hammers have been determined, track No. 3, by means of the punching lever *Z*, moves the hammer frame *F* forward (to the left in Fig. 82) carrying with it the five hammers *H*. When this operation takes place the punches opposite the hammers in the marking position are forced through the tape. The punches opposite hammers in the spacing position are carried forward until they meet the paper, but having no positive drive they slide back in their guides and do not perforate the tape (see Fig. 83). The tape is thus perforated in accordance with the positions of the five hammers which have been determined by the code received.

When the hammer frame is fully forward, track No. 4 moves the resetting lever *RL*, see Fig. 83, towards the lower extensions of the hammers, and on the hammer frame being moved to its rest position (to the right in Fig. 83) the hammers which have been set to the marking position are reset to the spacing position.

During the next start signal the resetting lever *RL* is moved to the right, (see Fig. 83), thus allowing the hammers to be set downwards as required. The paper tape is fed through the punch block by the tape feed

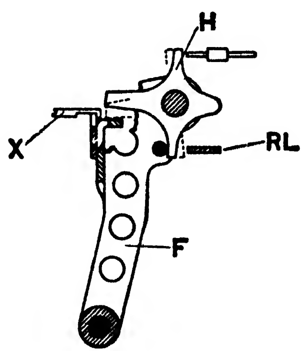


FIG. 83.

spindle *W*, which is operated by cam track No. 2 through the traversing lever *Y*, the feed rocker *SC* and the feed pawl *N* (Fig. 82).

The Perforator.

The perforator is an instrument which prepares the paper tape for controlling the teleprinter automatic transmitter.

The keyboard is similar to that of an ordinary type-

FIG. 84.—THE TFLFPRINTFR PERFORATOR

writer, and the depression of any key results in the perforation of the tape (see Fig. 84).

The perforator can, if desired, be associated with the automatic transmitter to form a compact unit.

The Combined Perforator Automatic Transmitter.

This unit has been designed to meet the demand for an efficient and compact assembly of perforator and automatic transmitter mounted on a common base and driven by a common motor. Special attention has been given to the arrangement of the components so as to conform with modern telegraph practice.

FIG. 85.—THE CREED COMBINED PERFORATOR-TRANSMITTER.

The perforator unit is designed to enable the operator to read up to, and including, the last letter perforated, and a back spacing lever is provided to enable invisible correction of typing errors to be made.

The tape platform on the auto-transmitter is placed as close as possible to the perforator so that a minimum time delay will occur between perforation and transmission. The automatic tape control unit provides a means for arresting the tape and stopping signal transmission should the operators' speed lag behind transmission speed.

One motor drives both the keyboard perforator and automatic transmitter units (see Fig. 85).

CHAPTER V

TELEX WORKING AND SUB-AUDIO WORKING

TELEX working enables subscribers who are on the telephone to be connected together via telephone circuits for the purpose of teleprinting. Half-duplex facilities are provided, each subscriber receiving a copy of his own transmission. Signalling is carried out over the ordinary local or trunk telephone routes at a voice frequency of 1,500 c.p.s. The principle of telex working is shown in Fig. 68, number 5, page 91.

Subscribers' Equipment.

Each subscriber is provided with the necessary equipment which includes a telephone, a teleprinter, power supply and V.F. converter, with the necessary switching devices (see Fig. 86). Communication is effected in a similar manner to an ordinary telephone call. The switch is placed in the *telephone* position and the number dialled, or if manual, passed to the operator. On the connection being established the called subscriber is requested to switch over to teleprinter. This is done by means of two coupled tumbler switches which may be thrown to positions marked *Telephone* or *Teleprinter* as required. The action of throwing the switch to the Teleprinter position, switches on the V.F. converter, the power to the motor, and changes the telephone line connections over to the teleprinter equipment. The telephone is replaced on the cradle and a few seconds

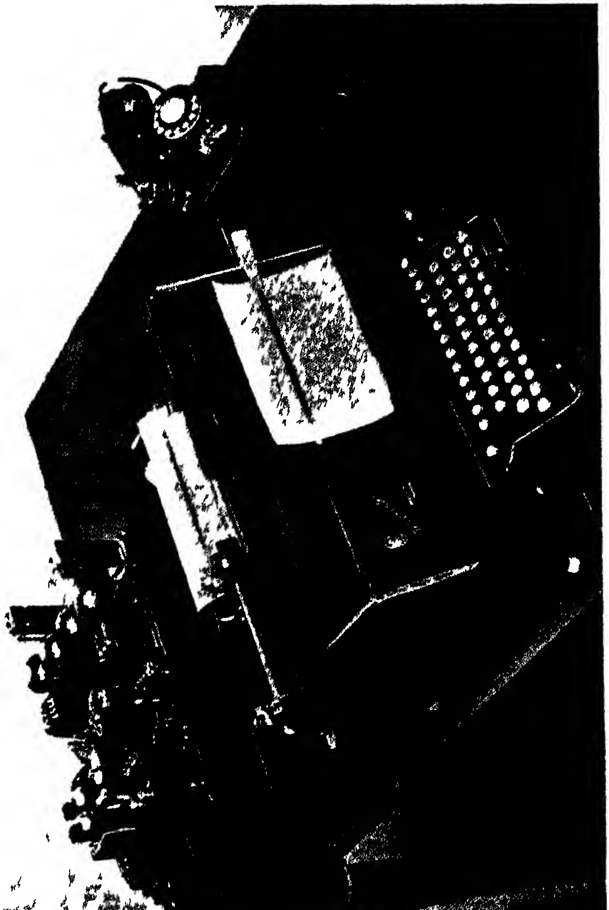


FIG. 86.—THE SUBSCRIBERS' TELEX INSTALLATION.

allowed for the valves in the converter to heat up. The calling subscriber and the called subscriber will each depress the *who are you* key in turn, to verify the connection before proceeding with the message. On completion each subscriber restores their switch to the *telephone* position which switches off the power and gives the necessary clear to the exchange.

The Voice Frequency Converter.

The schematic diagram of the V.F. converter is shown

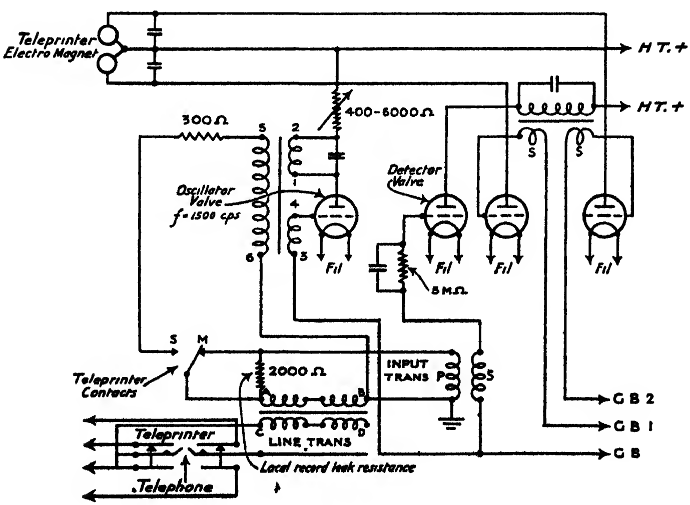


FIG. 87.

in Fig. 87. A received signal passes through the winding *CD* of the line transformer and induces a similar current in the winding *AB* in series with the primary of the input transformer, the circuit being completed at *M* by the teleprinter transmitting tongue. The current

induced into the secondary of the input transformer is applied to the grid of the detector valve via the 5 MΩ grid leak. The output from the detector valve flows through the primary winding of the push-pull transformer. The two secondary windings are connected to the grids of the push-pull amplifying valves in such a manner that the received current has an opposite effect on the grids of each valve. The grid of one valve becomes more negative whilst the negative bias on the other is reduced. The anode currents are affected in a similar manner, one being increased and the other decreased. Since each of these currents flow through half the electro-magnet windings and are opposite in effect the armature will move over to space, returning to the marking side on cessation of the signal.

The Oscillator.

The circuit of the oscillator is comprised of the valve and a three-winding transformer. Primary windings 4–3 and 1–2 are connected to the grid and anode circuits respectively. The secondary winding 5–6 is connected in series with the winding *AB* of the line transformer via the teleprinter transmitting tongue and a 300-ohm limiting resistance. Interaction between coils 1–2 and 3–4 cause self-oscillation of the valve. The anode circuit is tuned to 1,500 c.p.s. by the $0{\cdot}1\mu$F condenser across 1 and 2, and the volume is controlled by the variable resistance in the anode circuit. The secondary circuit is open when the teleprinter is at rest. Movement of the tongue to the spacing side completes the circuit and allows the signals to pass to line. When the secondary circuit is complete the oscillatory current also passes through the primary winding of the input transformer,

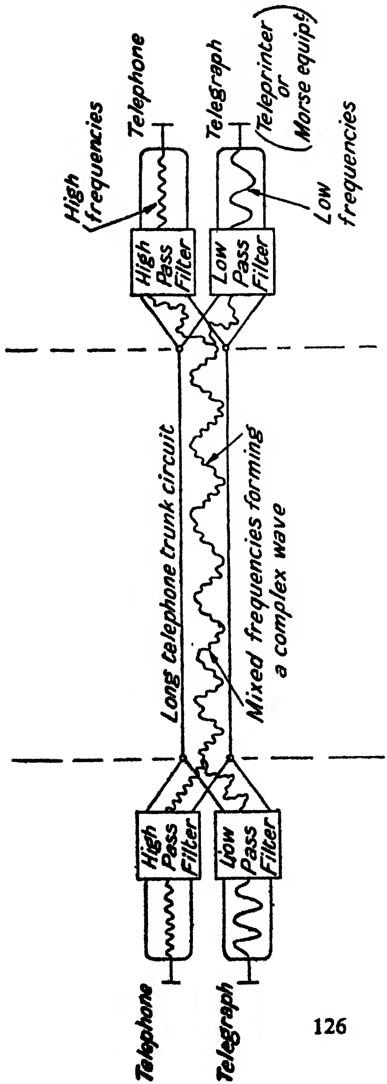


FIG. 88.—A SUB-AUDIO CIRCUIT.

which is in parallel with the secondary winding. The current produced in the secondary of the input transformer is applied to the grid of the detector valve and is used to provide a local record.

The 2,000-ohm resistance across the primary of the input transformer limits the amount of current used to supply the local record and prevents the detector valve from being overloaded.

Principle of Sub-audio Working.

In telephony, the range of frequencies required is 300 to2,700 c.p.s. Since the signal frequencies used in telegraphy are usually

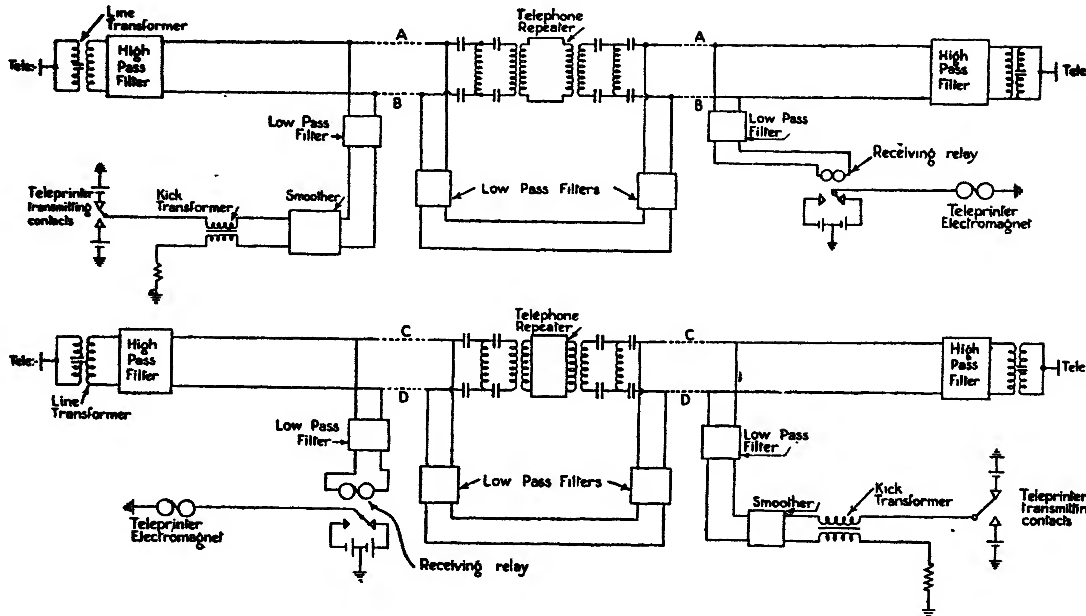


FIG. 89.—CIRCUIT ILLUSTRATING THE PRINCIPLE OF SUB-AUDIO WORKING.

low of the order of 25 c.p.s. (p. 24) it will be possible to work a telegraph and a telephone over the same line simultaneously if filters are provided to prevent the one interfering with the other. Such circuits are known as *composited* circuits. Another name given to this arrangement is *sub-audio* or more rarely *infra-acoustic* telegraphy (see Fig. 88).

The high-pass filters whilst allowing speech frequencies will prevent the telegraph signals from interfering with telephone transmission. Speech currents will not be of sufficient magnitude to interfere with the telegraph circuit.

A low-pass filter must be included at the sending end to prevent the harmonics of the telegraph signals from entering the line since these are of high frequencies and extended into the telephone range. They would therefore pass through the high-pass filters and cause interference to the telephone circuit.

A low-pass filter is necessary at the receiving end because the movement of the relay armature generates frequencies which are in the telephone range. These are prevented by the filter from passing back to line.

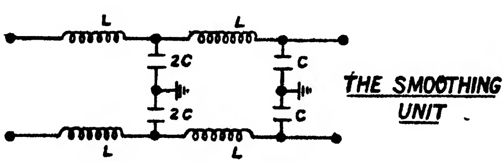


FIG. 90.

The high-pass filters have a lower cut-off frequency of about 200 c.p.s. and pass all frequencies above this. The low-pass filters usually cut off at about 60 c.p.s.

Ordinary telephone ringing current used on generator signalling trunk circuits has a frequency of 17 c.p.s.

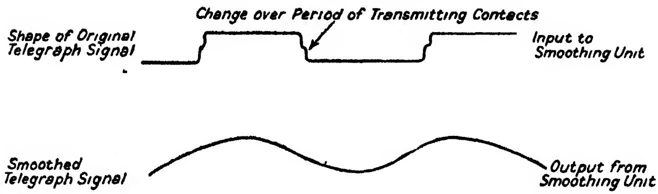


FIG. 91.

Since this comes in the telegraph range it is necessary to adopt some other frequency for the signalling current. A frequency of 500 c.p.s. interrupted 20 times per second is used.

All long-distance telephone trunk circuits are fitted with valve amplifiers and repeaters.

The efficiency of telephone repeaters at frequencies below about 200 c.p.s. falls off rapidly, so that in effect

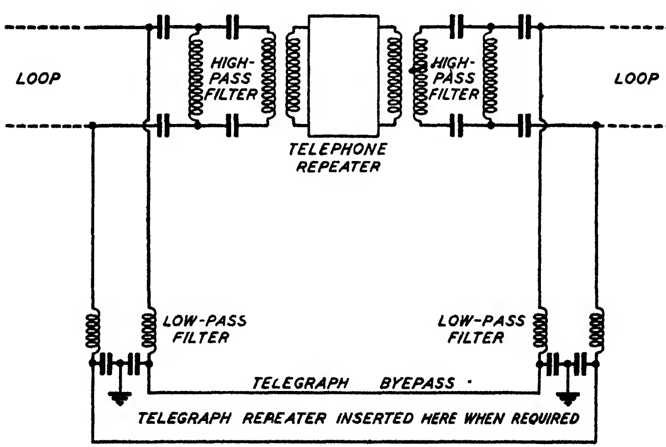


FIG. 92.—ILLUSTRATING THE METHOD OF BY-PASSING TELEPHONE REPEATERS.

low frequencies will not pass through them. To overcome this difficulty the repeaters have to be by-passed. This is achieved by routing the telegraph signals round the repeater via low-pass filters as shown in Fig. 92.

The two-wire telephone circuit in Fig. 88 permits telephone transmission in both directions but only undirectional transmission on the telegraph circuit. Telegraph transmission in the reverse direction is achieved on a second two-wire circuit as shown in Fig. 89. The majority of the present-day long-distance telephone trunk circuits are of the four-wire type, then telegraph transmission in one direction will be over the *A* and *B* wires and in the reverse direction over the *C* and *D* wires.

A long-distance telephone trunk circuit upon which a telephone and telegraph circuit are working simultaneously is shown in Fig. 89.

To reduce interference between the telegraph and telephone circuits to a minimum, smoothing units shown in Fig. 90 are fitted in series with the low-pass filters. The smoothing effect on the telegraph signals is shown in Fig. 91.

CHAPTER VI

VARIOPLEX TELEGRAPHY

REFERRING to the eighteen-channel V.F. telegraph system, we would probably find, if we could watch the telegraph traffic over these eighteen channels, each of which has the same band-width, that some channels are very heavily loaded whilst others are comparatively lightly loaded. We are not, therefore, getting the full capacity out of the system.

An ideal condition to obtain maximum capacity from the system would be for the busy telegraph stations to have access to the lightly loaded telegraph channels in addition to their own whenever the telegraph stations connected to the lightly loaded channels stop operating.

Facilities should also be provided whereby the non-sending telegraph offices could reclaim their channels when they require to transmit again.

The principle outlined above is the basis of The Western Union Varioplex Telegraph System, which provides each pair of stations connected together by it with an ever-ready both-way transmission circuit having a band-width of zero when idle and a variable band-width when busy, the extent of the band-width depending upon the number of other stations operating at the same time. It secures this result by allotting the channels of the system to the working stations only, so long as the stations have something to send. A busy station disengages its channel by becoming idle and re-enters by offering one letter for transmission. The system permits a large

number of small telegraph offices to be connected, since they do not occupy channels when idle. These offices under other channelling systems would not be given a direct circuit because of the small amount of traffic handled.

Multiplex Telegraph Systems.

The varioplex system is a time division Multiplex telegraph system, that is, it is dependent for satisfactory operation upon synchronism between the transmitting and receiving distributors.

In multiplex systems, a number of operators are successively given exclusive use of a telegraph channel for a period of time sufficient to transmit one character.

Signals are transmitted and received by means of segmented distributors at each end of a circuit. Successive segments on the distributor transmit the elements of the character code and the distributor can be constructed to enable several operators to be given consecutively the exclusive use of the line during the period of rotation of the distributors. By this means several messages can be transmitted over a single circuit at the same time. Duplex working can be obtained, thus permitting a maximum of eight simultaneous messages to be transmitted over a single circuit, four in each direction.

A five-unit code is used for signalling, and transmission is by double current. The distributor is divided into sections as required, three sections for a three-channel, and four sections a four-channel multiplex. In the sketch, Fig. 93, the channels are designated *A*, *B*, *C* and *D* and each channel sector is subdivided into five equal sectors. A transmitter is shown at *P* and a receiver at *Q*, each connected to channel *A*; there are similar trans-

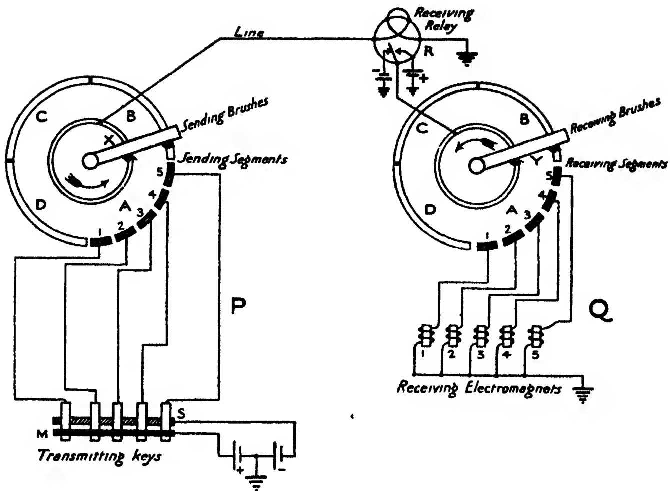


FIG. 93.—PRINCIPLE OF MULTIPLEX TELEGRAPHY.

mitters and receivers connected to channels *B*, *C* and *D*. The brush arms *X* and *Y* rotate in synchronism as shown and with the five keys of the transmitter normal at *P*, they make contact with the upper bar *M* and connect $+ve$ battery to segments 1, 2, 3, 4 and 5. When the distributor brushes pass over the segment at *P*, $+ve$ battery is extended to line and through the polarised relay *R* at *Q*. When a key is depressed at *P* it is connected to the lower bar *S* and this extends $-ve$ battery to the corresponding key sector and will be connected to line when the distributor brush passes over that sector. Double current signals corresponding to the character code set up on the keyboard of any channel are thus transmitted and operate the polarised relay which in turn repeats these signals to the corresponding receiving

electromagnets 1, 2, 3, 4 and 5 at *Q*. The selected operation of electromagnets at *Q* controls the selector and printing of the particular character transmitted. Printing occurs during the rotation of the distributor over the other channels and the electromagnets are then released ready for reception of another character on the next passage of the brush over that channel.

Synchronism or Phase Correction.

Synchronism between the transmitting and receiving stations is maintained by driving the distributors by phonic motors off vibrating reeds and transmitting a speed correcting current every revolution of the distributor at the *correcting* station.

In the Western Union Multiplex system, phase relationship between the sending and receiving terminals is controlled by the corrector on the receiving distributor operated by the incoming signals.

The corrector is mounted on the shaft of the receiving distributor and by means of an electromagnet and a ratchet mechanism it is possible to stop the rotation of the bushes momentarily.

As the receiving distributor is arranged to run at a speed slightly faster than that of the sending one, this check is sufficient to correct the tend of the brushes to run out of phase.

The received signal passes through two relays on arrival at the receiving station—the line relay and the corrector relay. The tongue of the line relay is connected to the solid receiving ring and current passes from there to the appropriate segments and then to the printer. Operation of the printer is completed by local pulses from a separate ring.

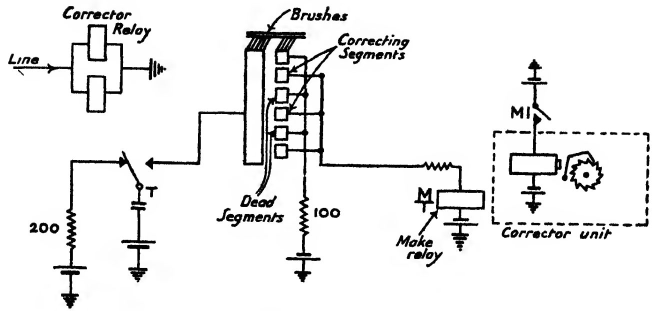


FIG. 94.—THE W.U. SYNCHRONISING CIRCUIT.

The circuit from the tongue and local contacts of the corrector relay is shown in Fig. 94, where for clearness the correcting segments have been developed linearly instead of orientated as in Fig. 93.

The theory is briefly this: the correcting condenser in the tongue lead *T* of the correcting relay is connected to the battery so that for every marking pulse the condenser will be charged and for every spacing pulse the condenser will be discharged.

Let us suppose that the line current reverses the relay tongue from spacing to marking and so charges the condenser through the corrector rings from negative battery. If the brushes are on a *dead* segment at that instant the charge current is derived from the 100 ohm battery and no correction takes place, but if the brushes are on a line segment, the charge current comes from a battery via the coil of the make relay in the synchronising unit.

This causes the make relay to operate and energise the corrector magnet which in turn operates the ratchet mechanism. It thus stops the rotation of the brushes momentarily, and restores the brushes to their correct position.

Fig. 95 is an analogy for a multiplex in the form of a belt conveyor carrying alphabet cards from three transmitting positions on the right to three receiving positions on the left. The sending dealer (or distributor) works downward, picking up one card from a channel at a time.

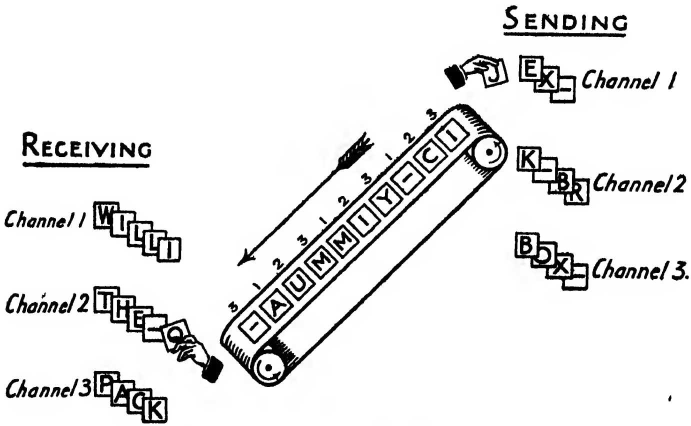


FIG. 95.—PRINCIPLE OF THE MULTIPLEX SYSTEM.

The receiving dealer distributes the cards as they arrive in a similar manner and in proper sequence. The letters on the belt in Fig. 95 seem to be badly jumbled, but if the reader will put himself in the receiving dealer's place, he will find that the letters form the correct words and sentences as soon as they are put into the proper channels.

If we assume, as in Fig. 96, that channel 3 has been closed out before its sentence, *PACK MY BOX*, had been started through the conveyor, nothing but blank cards would be available at the third channel for the sending dealer to put on the belt. The belt thus carries alphabet cards for channels 1 and 2, and blank cards for channel 3.

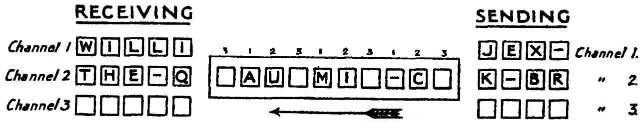


FIG. 96.—MULTIPLEX SYSTEM WITH CHANNEL 3 IDLE.

Numerals have been drawn above the letters in the diagram to indicate their respective channels. The receiving dealer, proceeding in sequence, must lay down blank cards as well as "live" cards in channel order as they arrive. This simple system, corresponding to the multiplex, would at such times waste one-third of the total lane space.

The Principle of the Varioplex System.

If the belt conveyor were operated on the varioplex principle, as in Fig. 97, the sending dealer would note the stoppage of transmission on channel 3 and throw a single blank card on the belt to indicate it. Thereafter he would skip channel 3 and would send out cards from channels 1 and 2 exclusively. When the blank card

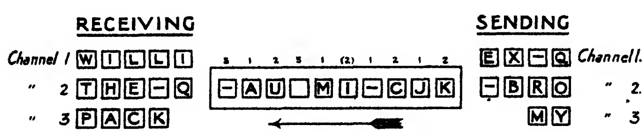


FIG. 97.—ILLUSTRATING VARIOPLAX PRINCIPLE. (CHANNEL 3 IDLE.)

arrives at the receiving end, the dealer there is to be imagined as distributing it in regular sequence to the third channel, as shown in Fig. 97. The receiving dealer interprets such a card as an indication of the closure of channel 3 and proceeds to skip that channel in the future. The lane now carries the cards of channels

1 and 2 at a more rapid rate because the third channel's position on the lane is no longer claimed and held by a string of blank cards, Fig. 98.

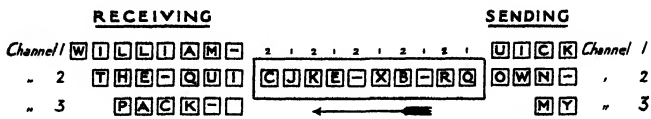


FIG. 98.

At this point it is advisable to anticipate the ultimate re-entry of channel 3 because the sending dealer cannot start third channel cards without notice. To this end small numbers may be imagined as painted on the belt below the cards to represent the moments at which

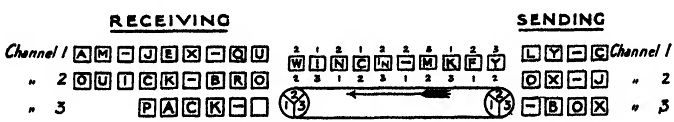


FIG. 99.—ILLUSTRATING RE-ENTRY OF CHANNEL 3.

channels 1, 2 and 3 can be entered (see Fig. 99). These numerals are employed solely for the entry of channels and have no relation to the channel identity of the cards that happen to be above them.

The sending dealer now proceeds to enter channel 3 by putting a card marked *in* on the next space designated by 3 that the belt brings up. The arrival at the receiving station of such a card in such a position is the cue for the receiving dealer to pick up the blank card from the third channel and, having discarded both the blank and *in* cards, include that channel in future distributions.

Channel 3 has been used as an example, but obviously the other channels of the varioplex can be entered, mixed,

and cut out in similar fashion. The belt numbers in Fig. 98 can be dispensed with if the rims of the pulleys are numbered correspondingly. The transmission of special signals, corresponding to *in* cards at predetermined times, interspersed among regular signals, is an important feature of the varioplex system, because the movement of traffic continues while additional channels are being entered and cut out.

Another way of entering channels is to show a *pattern* of the channel cut-in situation, i.e. to transmit a group of signals representing the status of a group of channels. *In* channels may be represented by marking pulses and *Out* channels by spacing pulses of the pattern signals. The complete pattern can be shown at a prearranged time, and that time always reserved for it at both ends of the lane. Another way of using the pattern is to introduce it into traffic by a special break-in signal, and in this case there is no delay at all in controlling the channels.

The Varioplex automatic telegraph system provides up to forty two-way point-to-point channels of communication over an entire standard double, triple or quad multiplex circuit of suitable frequency. These channels of communication, which terminate at each end in sending and receiving teleprinters, are referred to as *sub-channels*. Each sub-channel is continuously available for use but is actually connected only when communication is being carried on. This results in an efficient use of the multiplex circuit as idle sub-channels use no line time. Sub-channels, when connected to the multiplex circuit, share consecutively, character by character, in the use of the circuit. The operation of a sub-channel in one direction is independent of that in the other.

For purposes of description the Varioplex equipment,

exclusive of the sending and receiving printers and signal relay at the subscriber's premises, may be considered to be made up of three principal groups of apparatus. They are:

(1) Circuits and equipment for receiving signals from a sending teleprinter and recording them in the form of perforated tape which is fed to a transmitter; and for controlling the transmitter. Circuits for transmitting incoming signals to the receiving teleprinter.

(2) Circuits and equipment for connecting sub-channel transmitters to any of the multiplex channels of the system and for connecting multiplex channels at the receiving end through equipment to convert five-element signals to seven-element. If a quad multiplex is used, the principal equipment consists of four sending and four receiving line-seizing relays per sub-channel at each terminal, and associated with each such group of relays a control relay, the operation of which determines whether or not the sub-channel shall be connected to a multiplex channel.

(3) Circuits and equipment for operating the control relays associated with each sub-channel group of line-seizing relays. This equipment consists primarily of rotary switches and relays which operate the control relay at the sending terminal and transmit signals over two of the multiplex channels to cause the operation of the control relay at the receiving terminal, through a rotary switch and relay circuits.

Path of Signals from Sending Sub-Channel Teleprinter to Receiving Sub-Channel Teleprinter.

When a sending sub-channel teleprinter is operated, the transmitted signals may be traced through the entire system (see Fig. 100). Assume that some such signal is sent by the operation of the keyboard. The signal will pass through a monitor jack and switch located in a monitor unit associated with the particular sub-channel equipment. At this point it is possible, by the use of a printer, to observe these signals or to communicate with the sending sub-channel printer, or to transmit signals, through the varioplex, to the distant receiving sub-channel printer. Signals then pass to a receiving relay, or to a vacuum tube bank, the output of either being fed to a start-stop distributor. This distributor delivers the 5-unit code signals to a tape reperforator where they are perforated in paper tape. The paper tape then passes through a tape transmitter which is controlled by an autostop switch. Automatic tape feed-out mechanisms are provided at the reperforator so that those characters which have not been fed to the transmitter by following characters sent by the operator may be stepped through the transmitter. This automatic feed-out is timed so as to take place several seconds after the last character sent, thus permitting short pauses in the transmission without its occurrence.

The tape transmitter is provided with circuits which read the tape and determine whether a blank or a normal character is over the pins. A *normal* character is defined as one having one or more marking impulses and is usually referred to simply as a normal. Circuits associated with the transmitter will automatically feed the

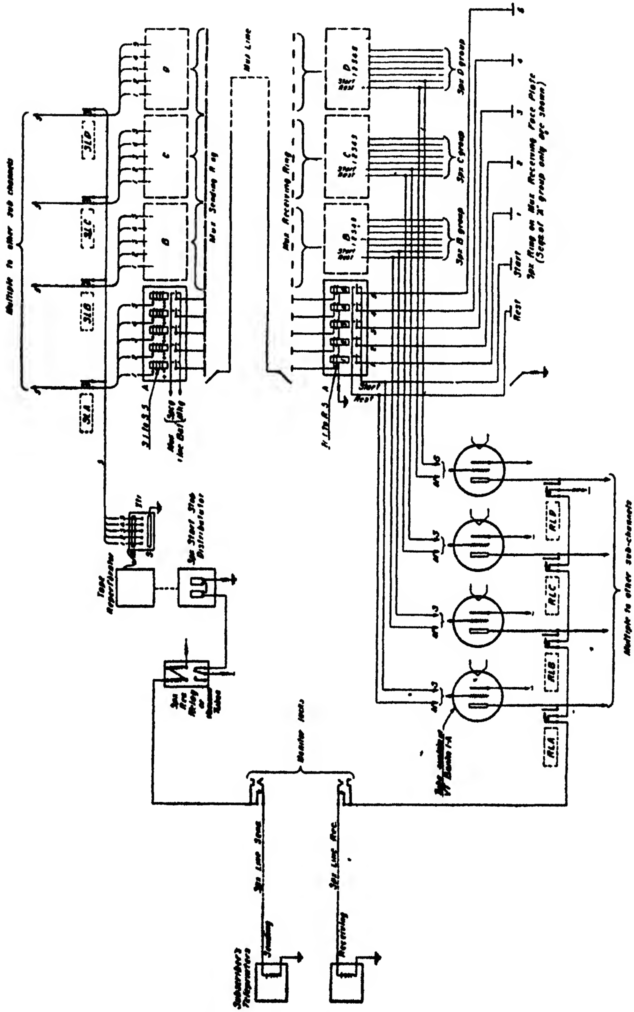


FIG. 100.—ONE COMPLETE VARIOPLEX CHANNEL.

blank characters which precede the sub-channel transmission through the transmitter without transmitting them to the multiplex circuit. When the first normal character appears over the transmitter pins, the transmitter is stopped and operations performed which connect it to a sending relay bank of a channel of the multiplex circuit through line-seizing relays. The operation of a control relay associated with each sub-channel group of line-seizing relays causes the proper one of them to operate. The control relay, in turn, is operated by the *cut-in* mechanism, the term *cut-in* being used to denote the connection of a sub-channel to the multiplex circuit and *cut-out* its disconnection. The time required to connect a sub-channel to the multiplex circuit may vary from 4 to 8 seconds after the first character is sent by the teleprinter.

The operation of the cut-in mechanism transmits signals over two of the multiplex channels which are read by the cut-in mechanism at the receiving end and there operate the proper control relay associated with the receiving line-seizing relays. When the sub-channel has been cut in, the transmitter again operates and sends the characters perforated in the tape. The circuits of the line-seizing relays and control relay are such that they operate automatically to connect the proper sub-channel at each end of the system to the same channel of the multiplex circuit. If only one sub-channel of a system is in operation, it will be connected to one of the multiplex channels. If two, each will be connected to a channel, and, assuming a quad circuit, a similar arrangement will result from the connection of up to and including four sub-channels. When more than four sub-channels are cut in they are connected to the multiplex

channels character by character, in consecutive order, so that each sub-channel in turn has an opportunity to transmit one character. This results in a varying speed of operation of the sub-channels depending upon the number of sub-channels in use at any particular time. If the multiplex channel speed is 66 words per minute with a quad multiplex circuit, and four sub-channels are in operation, the speed of operation of each sub-channel will be 66 words per minute. If more than four are in operation, the speed of each sub-channel will be the total capacity of all multiplex channels divided by the number of such sub-channels in operation. For example: five sub-channels will result in a speed of each sub-channel of 52·8 words per minute, six sub-channels will result in a speed of each sub-channel of 44 words per minute and so on for any number. The line-seizing relays at either the sending or receiving end, together with their control relays, are called a *relay chain*.

Operation of the transmitter is under control, not only of the character which may be over the pins, but also of an autostop. When the tape loop shortens, the autostop operates to feed out blank tape automatically and so pass the last character perforated through the transmitter. When blank characters, following the last normal character in the tape, pass through the transmitter, the cut-in mechanism is operated to disconnect the line-seizing relays from the multiplex circuit and to send signals over two of the multiplex channels to the receiving end to operate the control relays there and thus disconnect the receiving line-seizing relays.

At the receiving end, incoming signals operate five polar receiving relays, R_1 to R_5, for each multiplex channel and are stored there. Vacuum tubes are controlled by these

relays and by segments of a ring on the receiving distributor, which together convert the signals into seven-unit teleprinter code and transmit them through contacts of the receiving line-seizing relays and through a jack and switch in the monitor unit to the sub-channel receiving printer. Incoming signals may be monitored at the jack and provision is made for communicating with the receiving printer by the use of a printer and the operation of the switch.

SUMMARY OF OPERATION. The operation described in the previous paragraphs may be summarised as follows:

> Each sub-channel terminates in a sending simplex leg. Signals are sent and received by means of a teleprinter in each leg.
>
> Signals from the sending teleprinter are stored in five-unit reperforator tape at the main office. The tape passes through a multiplex transmitter which is connected by line-seizing relays to a multiplex channel.
>
> Incoming multiplex signals of each channel are converted to seven-unit simplex signals by segments of a ring on the receiving multiplex distributor and vacuum tubes from which they are connected through contacts of line-seizing relays to the receiving teleprinter.
>
> Sub-channels are automatically cut in or cut out in accordance with their traffic requirements.
>
> Only those sub-channels having traffic available share in the multiplex line time.
>
> If the number of cut-in sub-channels is less than the number of multiplex channels, each sub-channel is connected to a multiplex channel. If the number

is greater, each sub-channel in turn is connected to a multiplex channel and sends one character.

Autostop Arm.

The autostop arm is associated with the automatic transmitter and indicates to the varioplex system that its channel is without traffic and requires entry or exit.

When the prepared tape passes under the autostop arm after perforation by the reperforator, the arm is lowered, and the coil of the channel cut-in relay becomes de-engerised, but on the cessation of incoming signals from the subscriber the tape between the reperforator and the transmitter tightens and the arm is raised. This closes a contact which energises the cut-in relay and thereby stops the transmitter. Contrariwise, on the arm becoming lowered again the relay de-energises and allows the transmitter to operate at the proper time.

Signals to the Subscriber.

To prevent too great an accumulation of tape at the Varioplex Terminal due to the subscriber sending at a greater speed than the varioplex channel, a warning current is sent to the subscriber which lights a *stop* lamp when the loop of prepared tape between the reperforator and the transmitter is of a length equal to 200 centre-holes. The subscriber should then stop transmitting until the light is extinguished, when he can recommence. If the varioplex channel allotted to the subscriber is in trouble, this same lamp may be caused to light by the varioplex attendant sending a reverse battery on the subscriber's sending line. In the case of subscribers supplied with automatic transmitters the arrangement is made to function so that the transmitter

is automatically stopped when the light is operated. Thus allowing the varioplex attendant to control sending when necessary.

Transmission of Last Character and Tape Feed Out.

If transmission from the varioplex transmitter fed by the subscriber's prepared tape stopped instantly the tape tightened, it would prevent some thirty prepared characters on the tape to be transmitted until the loop or slip allowed the transmitter to re-operate.

An arrangement has been fitted to the reperforator to prevent this and is called the blank tape feed out. Briefly, the operation is as follows: On the cessation of the reperforator operation a timing device, worked by a cold cathode tube, comes into operation which enables the reperforator to feed out blank tape for a length of about thirty centre-holes, the length of tape being adjusted to suit the distance between the reperforator and the transmitter on the varioplex rack.

Conclusion.

The varioplex telegraph system is used extensively in America and has proved very satisfactory in operation. In 1943 the Western Union Telegraph Company introduced varioplex working on their submarine cable between Britain and America and twelve important Government Departments in Great Britain were connected by this means to twelve Government Departments in America.

This was a definite advancement in submarine cable telegraph technique; previous to its introduction these Government offices had been compelled to send their telegraph traffic to the cable companies by teleprinter, for re-transmission from cable offices over the cables to the

distant termination. Furthermore, the fact that the varioplex establishes point to point both-way circuits, personal contact between the respective Government Departments on both sides of the Atlantic was established, and immediate acknowledgment of transmitted messages obtained.

The service over this system has been satisfactory and remarkably free from stoppages due to system failures.

The increase in the efficiency of utilisation of trunk-circuit capacity effected by the use of varioplex equipment is an obvious and worth-while contribution to telegraph progress. The dissociation of stations for point-to-point communication from the use of trunk-circuit capacity, except when traffic is actually being transmitted, is reflected in a greater return on investment in lines and terminal equipment. In planning point-to-point circuits for the handling of commercial telegraph traffic, traffic officers need no longer be bound by former limitations as to traffic volumes. To establish a direct channel of communication, a volume of traffic sufficient to justify the use of a fixed amount of trunk-circuit capacity represented by at least one full trunk channel has in the past been necessary. Assuming that the total traffic between the areas concerned justifies the use of varioplex equipment as many individual telegraph stations as needed can be set up, it being necessary for the loads on these individual stations to be sufficient to justify only the telegraph station equipment and the equipment for connecting it into the varioplex system.

CHAPTER VII

PICTURE TELEGRAPHY AND THE HELL PRINTER TELEGRAPH SYSTEM

THE Hell Printer System is a wireless telegraph system invented by the German engineer, Hell, and developed by the Siemens Halske Company. The Hell printer system combines the principles of Picture telegraphy and printing telegraphy.

To enable the reader to follow the working of the Hell printer system it has been decided to outline briefly the principles of picture telegraphy.

Picture transmission systems incorporate certain main principles in their working. Briefly these can be stated as follows:

> A *sender* which is arranged to scan in a regulated manner, by means of a light spot, the original picture to be transmitted. The variations in tone value of the original are interpreted into variations in amplitude of alternating current transmitted into the circuit.
>
> A *receiver* in which light from a constant source is arranged to fall on a piece of photographic paper or film, and scan these at exactly the same rate as the *sender* light spot. The variation of incoming power from line, operates a light valve which controls the intensity of light falling on the photographic material, which, with suitable treatment, gives a photographic reproduction of the original transmitted.

It is essential that accurate synchronism be

maintained between the sender and the receiver, and that the picture be received in proper phase relationship with the picture sent.

A schematic arrangement of the Siemens-Karolus-Telefunken system for the transmission of pictures is given in Fig. 101.

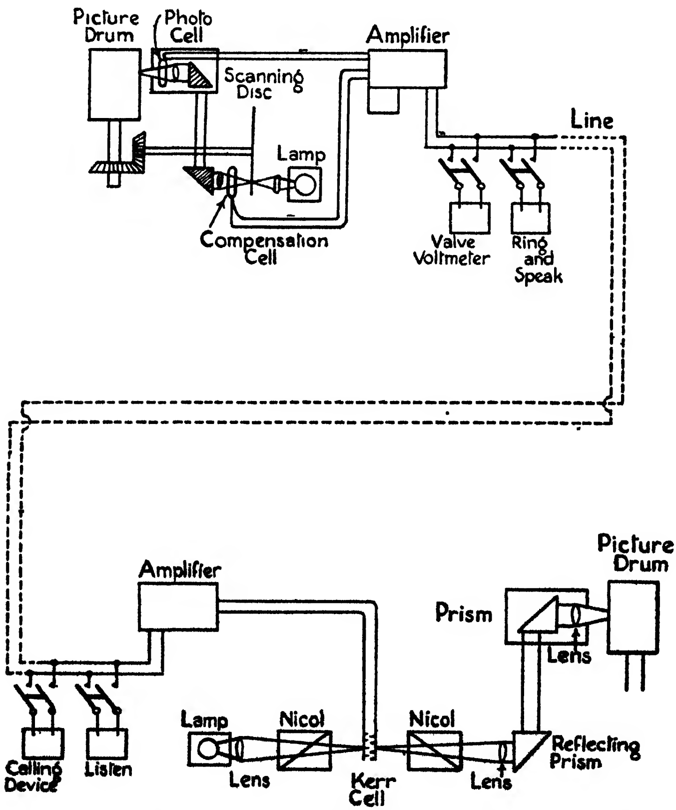


FIG. 101.—ILLUSTRATING THE PRINCIPLES OF PICTURE TELEGRAPHY.

The original to be transmitted is clipped on to a cylinder or drum arranged to rotate at a constant speed of 1 rev. per second. A D.C. motor whose speed is controlled by a synchronous motor from a tuning fork and amplifier provides the driving force. Light from a lamp is interrupted by the teeth in a uniformly rotating disc and focussed by an optical system on to the cylinder. The degree of light reflected on to a photo-electric cell, placed co-axially with the light beam, varies according to the absorption of light at the particular spot upon which the light beam falls. The output of the photo-electric cell varies with the amount of the reflected light falling upon it. These variations are fed to an amplifier and thence transmitted to line.

Mechanical arrangements and gearing provide for the light spot to scan the picture sequentially from one side to the other in a series of lines:

(*a*) At a linear speed corresponding to the speed rotation of the cylinder;

(*b*) With the fineness of scanning controlled by a traverse gear.

At the receiving end the cylinder and the mechanical arrangements, both for driving and scanning, are almost identical with those at the sending end. The incoming variations of power from the line are amplified and fed to a Kerr cell, which is filled with nitro-benzol. The latter substance possesses the property of rotating plane-polarised light under conditions of electrical strain. A beam of light from a lamp is polarised by a nicol prism and passed through the Kerr cell, and thence to a second nicol prism, orientated with respect to the first nicol prism. The Kerr cell and its optical parts act as a light shutter with no measurable inertia. The degree of light

emerging from the second nicol prism is thereby controlled by the electrical pressure on the Kerr cell, which is indirectly controlled by the tone shades in the original picture. The light beam which varies in intensity, is focussed on to a photographic film or sensitised paper, clipped on the receiving cylinder. Suitable treatment produces a negative or positive print according to the electrical arrangements and photographic treatment employed.

To sum up, with picture telegraphy the matter to be transmitted whether a picture or page of print, is scanned photo-electrically in successive narrow strips, and reproduced at the receiving end by what amounts to a reversal of the transmitting process. It will be appreciated that the electrical signals transmitted in picture telegraphy are directly related to the visual appearance of the matter concerned and are linked with it by an arbitrary code.

Now it is well known that radio reception is liable to be marred by *fading* and by atmospheric disturbance. Under such conditions signal elements of a radio telegraph message can occasionally be suppressed due to fading, and false elements will be inserted by atmospheric *noises*. If an arbitrary code is being used such alterations will completely alter the sense of the received message. An experienced telegraphist receiving morse by ear can make an intelligent guess at the meaning of such signals, but a teleprinter can exercise no such discrimination, and a wrong letter will be printed. With picture telegraphy, however, such disturbances can only result in the appearance of black or white specks on the received picture, a defect which rarely makes the picture unrecognisable.

Impulse Trains.

It was this good feature in picture telegraphy which prompted the German engineer Hell to apply the same principle to a printing telegraph. His original instruments have been developed and commercialised by Siemens and Halske and are now widely used for wireless telegraphy under the name of Siemens-Hell Printer. In this system each letter of the alphabet is imagined as laid out on a rectangular grid of seven (originally twelve) units either way (see Fig. 102). If such a letter were scanned photo-electrically, as in picture telegraphy, one vertical strip at a time, from left to right, the electrical impulse sequence would be as shown in Fig. 103. In the Hell transmitter, therefore, each letter is represented by a cam-disc having its periphery cut in a manner corresponding to such an impulse train (Fig. 104). When the instrument is in use all these

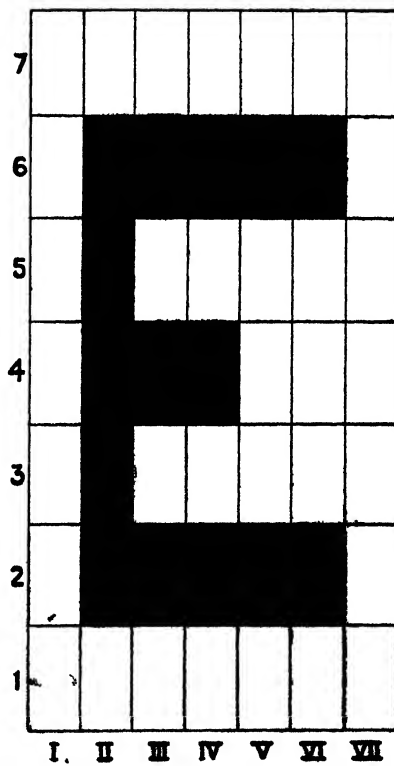


FIG. 102.

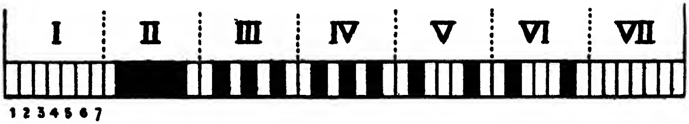


FIG 103.

discs rotate on a common spindle at uniform speed. Above each disc and just clear of it, is mounted a pair of contact springs: all these pairs of contacts are wired in parallel in the control circuit of the telegraph line or radio transmitter. The contacts are normally separated, i.e. no signal is sent out, but when it is desired to send out a particular letter a tongue of metal is inserted between the corresponding cam-disc and the lower spring of the

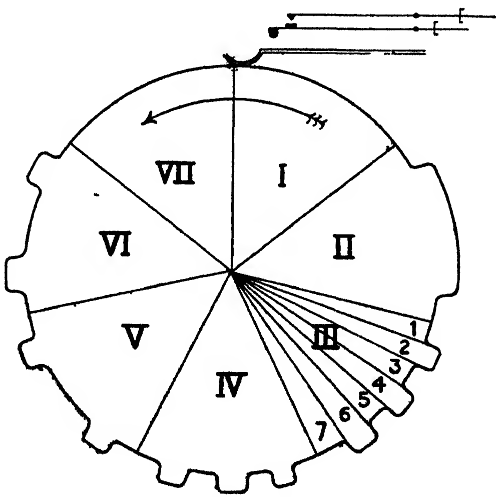


FIG. 104.

associated contacts. The cam then causes the contacts to close and open and send out to line a series of impulses precisely similar in their timing to those which

would have been produced by scanning the same letter strip by strip in a picture-telegraph transmitter.

Practical Forms of Transmitter.

The transmitter is made in two forms, manual and automatic. In the former the insertion of the tongues between the cams and their associated contacts is effected by the operation of a keyboard similar to that of a typewriter. In order to guard against the depression of a second key while a letter is on course of transmission, a mechanism actuated by a cam on the main cam spindle locks the keyboard except for a short period in each revolution. Rhythmic operation of the keyboard is thus essential. The speed of this machine is 2·5 letters per second. In the automatic transmitter which runs at double this speed, the insertion of the cam-following tongues is controlled by a perforated strip of paper exactly similar to that used in the teleprinter automatic transmitter, i.e. having holes corresponding to the *marks* of the five-unit teleprinter code punched in rows across the width of the strip. This paper-strip is prepared beforehand on a perforating instrument with a keyboard-like typewriter. The principle is essentially the same as that used in the Jacquard loom, where the combinations of heddles required for the weaving of a complicated pattern are selected in rapid succession by the automatic exploration of a previously perforated card.

Receiving Equipment.

The receiving apparatus is very simple in its operation. As will be seen from Fig. 105, it consists of (*a*) an electro-magnet having a blunt knife-edge on the extension of its pivoted armature; (*b*) a spindle with a raised helix on its

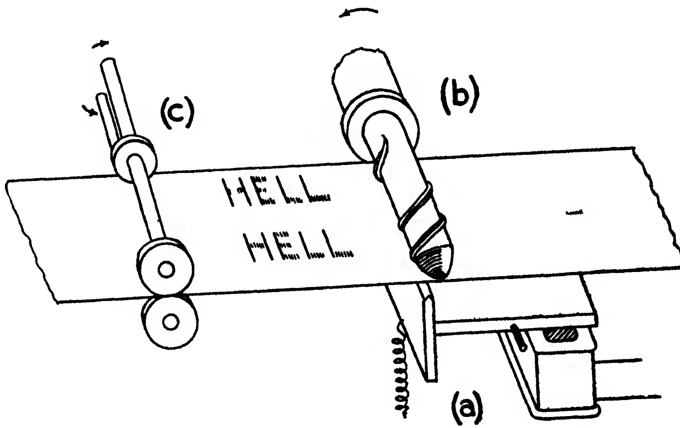


FIG. 105 —THE RECI IVING ELEMENIS.

surface, mounted above and just clear of the knife-edge, and rotating seven times as fast as the cam shaft of the transmitter; (*c*) a device for feeding a strip of paper slowly between the knife and the helix. An impregnated felt roller (not shown) riding on the helix keeps it moistened with ink. When the electromagnet is energised, i.e. when a signal is received from line, the knife-edge presses the paper strip against the rotating helix and causes a line to be drawn across the strip by the point of contact. According to whether the signal received is continuous (—————) or broken (— — — — —) so either the armature will be permanently attracted and a continuous line be drawn across the paper or it will be alternately attracted and released, giving a broken line across the paper. The slow continuous feeding forward of the paper-slip causes the lines to slope slightly and to follow each other across the paper in regular succession. The letters are thus built up from small elements, just as in

picture telegraphy but with this difference, which in news transmission is all-important, that as each letter is visible and intelligible it can be read without any waiting for the complete message to be printed, developed and fixed. In order that each letter shall be printed completely at least once in the width of the paper slip, the printing helix is taken twice round its spindle.

Thus there are two points of contact between the helix and the paper and two impressions of each letter are produced in the width of the paper. One impression may be divided but the other will always be complete. The effect of a discrepancy between the speeds of the transmitter and receiver is that each transverse line is staggered with respect to the preceding one, and the lines of print thus run off the paper in a direction depending on which machine is the faster and at an angle depending on the magnitude of the discrepancy in speed. One impression of each letter will; however, be complete and legible.

Fig. 106 shows the appearance of the printed strip typical of (*a*) perfect synchronism; (*b*) receiver running fast; (*c*) receiver running slow.

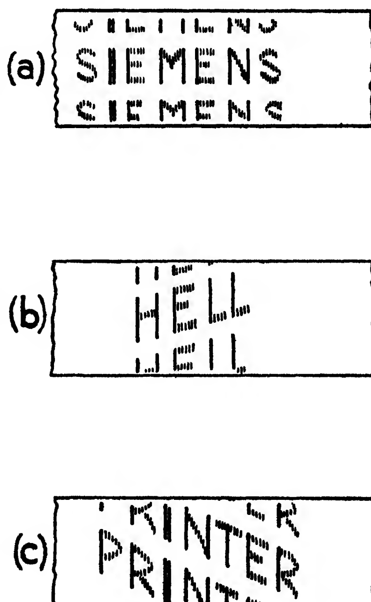


FIG. 106.

The receiver is fitted with a combined centrifugal governor and speed regulator which can be adjusted while the machine is running. It is thus easily possible to remove any obliquity in the lines of print without interrupting reception.

From the foregoing it will be appreciated that, where Hell instruments are used on a radio link, the effect of fading is to suppress the incoming signal, with the result that the armature is not attracted and no line is printed, whilst atmospheric *noises* cause the armature to be attracted when it should not and marks to be made where the paper should be blank. Even when these disturbances are of sufficient magnitude and duration to make teleprinter or morse working by radio impossible, they rarely preclude Hell working.

Applications of the Hell System.

The chief use to which Hell system has been put is the broadcasting of news by press agencies. As the traffic in such circumstances is in one direction only and is not necessarily continuous, it is desirable that the transmitting station should be able to start and stop the motor of the distant receiving machine. This is effected by sending a special signal of greater length than those occurring in the transmission of letters.

For use in permanent situations, the automatic transmitter has practically ousted the keyboard instrument. The latter has, however, recently found wide use in simplified and portable form known as the Siemens-Hell Fieldprinter. This instrument, designed primarily for operation from two car batteries, has a normal transmitter, receiver and appurtenances all under one cover. The chief simplification is in the transmitter, where the cams

have been replaced by a drum made up of a series of rings with conducting and insulating segments. The contacts and cam-following tongues of the normal transmitter are replaced by brushes which are brought into contact with the drum by the operation of the keyboard. Enough has been said to show how novel, yet simple in conception, the Hell system is. The keyboard transmitter and the perforator on which the punched slip for the automatic transmitter is prepared can be operated by typing staff, whilst reception involves only periodic collection of the printed slip and occasional slight adjustments to the speed regulator. Furthermore, both the transmitter and the receiver are comparatively simple to maintain. Why, then, has this system not been more widely adopted? The answer is a very familiar one: "You can't get anything for nothing." The fidelity of reproduction afforded by the Hell system is only gained at the expense of transmitting for each letter a number of signals far greater than is required in any other system of telegraphy.

If the rate of printing letters is to be comparable, therefore, with other systems, the number of signals to be transmitted in a given time will be correspondingly greater than in these systems. This feature limits the number of such telegraph channels which can be accommodated within a given frequency band, and for working on land lines free from interference currents, places the Hell system at such a disadvantage compared with, say, the teleprinter, as to exclude it from this field. For use on radio links, however, the Hell system is almost unrivalled and, unless some really effective direct means of counteracting fading and atmospherics is developed, may well become the standard telegraph system for radio working.

CHAPTER VIII

REMOTE CONTROL W/T TRANSMISSION AND RECEPTION

REMOTE control transmission is the method used in wireless telegraphy whereby a wireless telegraphist or morse operator has control of a distant wireless transmitter. For example, the wireless telegraphists in the Whitehall radio transmitting room can control transmitters in practically any part of the British Isles. This is accomplished by means of landlines, i.e. physical circuits or channels in a multi-channel voice frequency telegraph system, from the transmitting or controlling radio room to the transmitter site, as shown in Fig. 107.

The two methods of remote control of a transmitter are:

Direct current keying via a telegraph relay.
Tone keying.

Direct Current Keying.

In this method of control, operation of the key at the sending radio office connects an earthed battery to the line which in turn operates the telegraph relay at the transmitter terminal station. The contacts of this relay are made to open and close the circuit of the transmitter (see Fig. 107a).

Tone Keying.

In tone keying the audio frequency tone used to modulate the transmitter is generated near the operator's

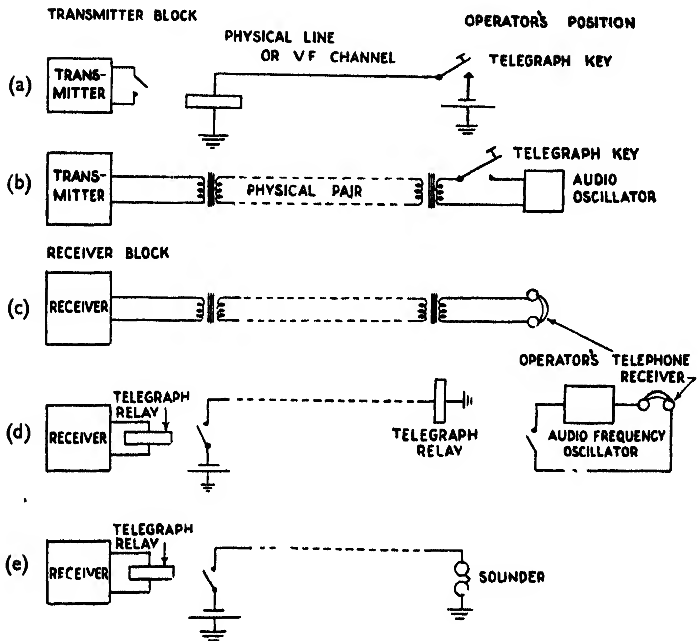


Fig. 107.

position at the sending office, the keyed tone being extended via a two-wire circuit to the transmitter. On very long circuits it will be necessary to insert amplifier repeaters at intervals in the circuit. Fig. 107(b) shows the circuit arrangement.

It will be appreciated that the above circuits will only permit transmission in one direction, and as it is often necessary for the transmitter terminal station to be able to signal to the sending station, *both-way* circuits are usually provided. A typical circuit is shown in Fig. 110.

Remote Control Reception.

In a somewhat similar manner Remote reception can be achieved, that is, the radio operator receiving the Signals is remotely situated from the receiving aerials. A typical example is one of the Admiralty's Main Receiving Stations, H.M.S. *Flowerdown*, which is situated near Winchester, Hants. Here the wireless aerials receive messages from Colombo, Simonstown, Ceylon, etc., and relay them on to Admiralty, London, via land-lines connecting the two establishments.

Methods of Remote Control Reception.

The method used to link up the receiving operator with the receiver is usually one of the following:

(1) Direct tone reception.
(2) Indirect tone reception.
(3) Sounder reception.

(1) Direct Tone Reception. The audio output of the receiver is passed via a two-wire line to the operating position. If necessary line-transformers and amplifiers may be incorporated. See Fig. 107 (c).

(2) Indirect Tone Reception. The receiver output is utilised to operate a telegraph relay the contacts of which connect a D.C. potential to the physical line. At the receiving operator's position line current operates another telegraph relay, the contacts completing the circuit of an audio oscillator and telephone receiver. The arrangement is illustrated in Fig. 107 (d).

(3) Sounder Reception. As for indirect tone reception, the receiver output operates a telegraph relay which applies D.C. to the line. At the operator's position the incoming current operates a sounder or printer either directly or via a relay, Fig. 107 (e).

Remote Control W/T Methods.

The usual method of remote control transmission and

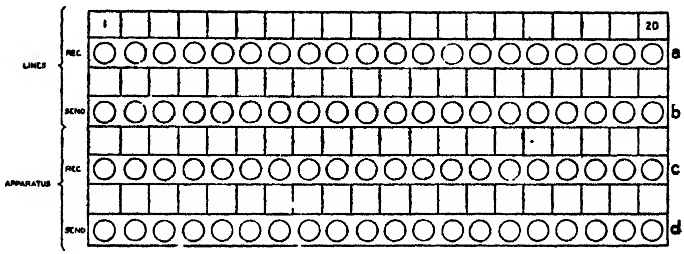


FIG. 108.—FACE LAYOUT OF A SECTION OF THE REMOTE CONTROL LANDLINE SWITCHBOARD OR JACKFIELD.

reception adopted is that of direct current signalling, with buzzer, sounder, morse printer or teleprinter reception.

Each large W/T Station is fitted with a remote control landline switchboard and the circuits terminated thereon in accordance with standard diagrams, depending upon the facilities required. Typical diagrams are shown in Figs. 109–13.

The Remote Control Landline Switchboard or Jackfield.

The remote control landline switchboard has been introduced as a component part of the radio remote control system in order that the following facilities may be obtained:

(*a*) Flexibility of landline connections whereby lines can be switched immediately, either for the normal use of alternative transmitters or for the provision of alternative routes (to a transmitter) in the event of line failure due to enemy action or other causes.

(*b*) Flexibility of operators' positions in the wireless rooms, whereby any set of morse or five-unit apparatus may be interchanged with another set, or associated with any one, or a group, of the outgoing lines, thus easing operating and maintenance conditions.

(*c*) Monitoring on through connections set up in the intermediate wireless room.

(*d*) Grouping lines for control by one key, either at the station where the lines are grouped for broadcast, or from a distant station.

Switchboard Operating Procedure.

Fig. 108 represents the face layout of the switchboard,

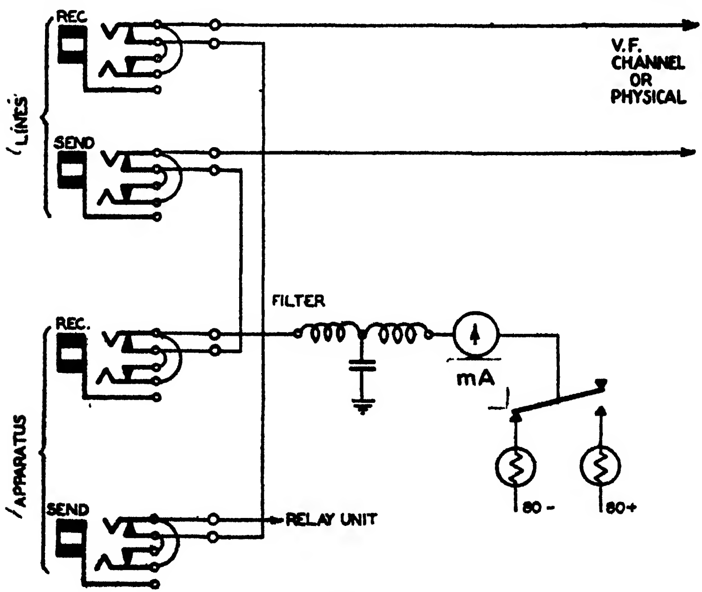


FIG. 109.

which is built up in groups of four strips of jacks. From a perusal of Figs. 108 and 109 it will be seen that all lines terminate on the (*a*) and (*b*) and all apparatus on the (*c*) and (*d*) jacks.

The (*a*) jack is marked REC, which means that at that point current is being *received* from the line.

The (*b*) jack is marked SEND, which indicates that at that point current is being *sent* to line.

The (*c*) jack is marked REC, which means that at that point current is being *received* from say, the morse key.

The (*d*) jack is marked SEND, which indicates that at that point current is being *sent* to the sounder.

NORMAL. Under normal conditions, i.e. when all

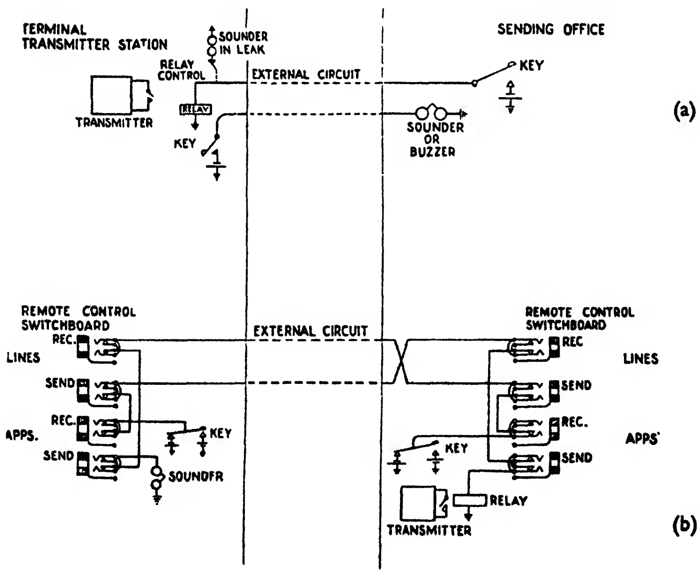


FIG. 110.—A BOTHWAY REMOTE CONTROL CIRCUIT ROUTED VIA JACKFIELDS.

keying positions are working to their lines, the face of the switchboard will be clear, that is to say no plugs and cords will be inserted in any of the jacks. One complete bothway circuit routed via a jackfield at each end is shown in Fig. 110 (b).

EXTENDING A LINE. When it is required to *extend a line* (i.e. to join one line through to another one), one end of a double-ended plug and cord is inserted in the line REC jack of one circuit, and the other end inserted in the line SEND jack of the other circuit. The extension is then completed. Monitoring can be achieved by extending the receive line via the monitoring equipment to the Send line by means of double-ended cords.

Grouping.

When it is required to transmit, or broadcast, to a number of stations simultaneously, master jacks and grouping jacks are used (see Fig. 111). The facility can be used in two ways:

(1) The station sets up the required lines and makes the broadcast.

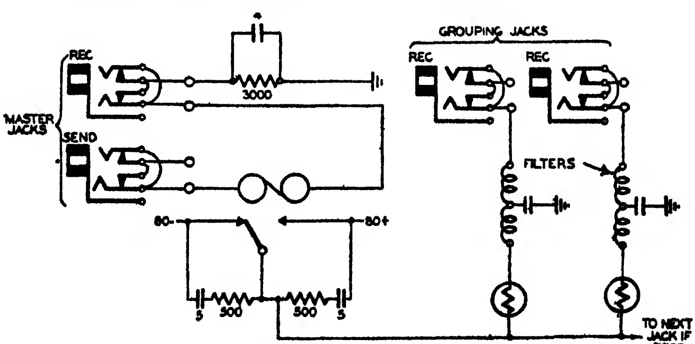


FIG. 111.—BROADCAST ARRANGEMENTS VIA THE REMOTE CONTROL JACKFIELD.

(2) The station sets up the required lines for a distant station to make the broadcast.

In the first case the morse set which is to be used to make the broadcast is plugged to the master jacks, and in the second case the line from which the broadcast is to be made is plugged into the master jacks.

Local Station Controlling Broadcast.

This is arranged by plugging the morse set or teleprinter to be used for broadcast into the master jacks, and the lines to the stations to be broadcast to into the grouping jacks. Current pulses from the transmitting morse key operates the master jack relay, the tongue of which extends similar current impulses via the grouping jacks to the receiving stations.

Distant Station Controlling Broadcasting.

This is arranged by plugging the distant line into the master jacks in exactly the same way as monitoring, and plugging the required lines into the grouping jacks.

The first method keeps a sounder in circuit for monitoring but limits the broadcast to the number of grouping jacks provided, while the second method provides broadcast up to one more station than the number of grouping jacks provided but does not keep a sounder in circuit for monitoring.

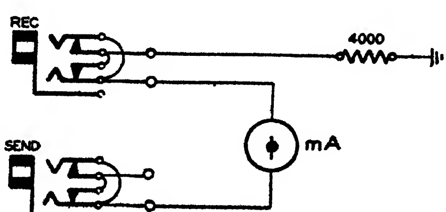


FIG. 112. VISUAL MONITORING CIRCUIT.

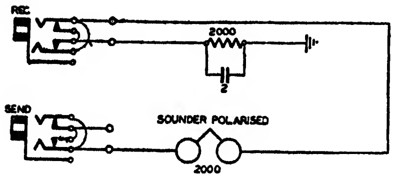


FIG. 113.
SOUNDER MONITORING CIRCUIT.

Monitoring.

Monitoring is effected by connecting by means of cords either a teleprinter sounder or milliammeter in series with one leg of the circuit. Figs. 112 and 113 show typical monitoring circuits.

CHAPTER IX

HIGH SPEED MORSE TRANSMISSION AND RECEPTION. THE CREED AUTOMATIC SYSTEM AND EQUIPMENT

WHERE speed of working is of primary importance, the use of high-speed automatic equipment is the logical development. It will be appreciated that an automatic transmitter could be substituted for the telegraph key in Fig. 110 (a and b); in fact, this is the modern practice. In a similar manner high-speed remote reception can be used, a reperforater and morse printer replacing the sounder in Fig. 110 (a and b).

The Creed High Speed Morse System.

This system, which is a development of the Wheatstone automatic system, is particularly suitable for operation over long and difficult landlines and submarine cables, or for radio work: it provides a single channel over which messages are transmitted at high speed in the morse code and recorded in printed Roman characters.

At the sending station the messages are prepared by as many operators as are necessary, each typing on a keyboard perforator which punches holes in a paper tape, representing signals in the morse code. The perforated tape is then passed through a Creed automatic morse transmitter. In this unit, two needles translate the perforations and cause currents to be transmitted to the line in the form of the well-known dot and dash signals

of the morse code. The transmission speed may be 10 to 200 words per minute according to the volume of traffic and the limitations of the line.

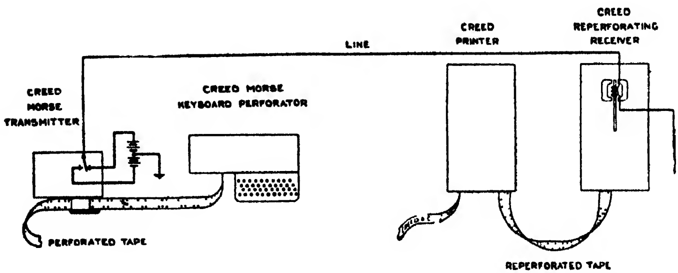


FIG. 114.—THE PRINCIPLE OF THE CREED HIGH SPEED MORSE PRINTING SYSTEM.

At the receiving station the incoming high-speed signals are received and reproduced by a Creed morse receiving reperforator as perforations in a paper tape identical in every respect with the original tape prepared at the transmitting station. This tape is then passed through a Creed morse printer which translates the perforations and prints the message in Roman characters on a paper tape or in page form, according to the type of printer used. Fig. 114 shows the arrangement of the apparatus.

The paper received from the reperforator may, of course, be used also for retransmission purposes.

The system can be operated on a Simplex basis, i.e. one direction at a time, or a Duplex basis, in which both directions operate simultaneously. The speed of operation can quickly be adjusted to meet varying line conditions; and as the morse code is employed, the signals can be read by sight or sound.

The morse tape printer will work satisfactorily at a speed of 120 words per minute, but 100 words per

minute may be considered a reliable speed for continuous use. The morse page printer may be operated at 80 words per minute with safety.

Accurate synchronism between the machines at each end of the line is not necessary as the receiving reperforator provides a sufficient margin of correction to allow of considerable differences in speed.

APPLICATION TO RADIO. The Creed high-speed morse transmitter is operating with conspicuous success on radio services, the signals being received by means of undulators. The R.M.S. *Queen Mary* is equipped with two transmitting sets and one undulator and transmitting and reception speeds of 100 words per minute have been obtained.

The tape transmitter controls a highly insulated polar relay, the contacts of which control one of the grid circuits of the radio transmitter.

Morse Transmitter (Wheatstone Code).

The Creed morse transmitter is a simplified form of the ordinary automatic Wheatstone transmitter. It translates, at high speed, perforations in a tape, prepared on a Keyboard Perforator or Hand Perforator, into corresponding morse code signals for transmission over the line.

It consists of a transmitting head and a motor-driven mechanism which provides a continuously variable speed-drive for the perforated tape which controls the mechanism in the transmitting head. The transmitting head, motor, change-speed gear, transmitting relay and control unit, form a compact transmitting equipment. The transmitting head is designed in such a manner as to be detachable for inspection, cleaning and adjustment.

Operation of the Creed Morse Transmitter.

Two important features of the Creed morse transmitter are that it possesses neither a bias lever nor a jockey roller, and that the moving contacts are mounted directly on the bell-cranks. Each bell-crank has a pecker, or needle, attached to one arm and a contact to the other arm. A spring attached to each bell-crank tends to hold its pecker in the *up* position. A rocking beam, or

FIG. 115.—THE MORSE TRANSMITTING HEAD.

eccentric lever rocks the bell-crank against the tension of the springs and in definite relationship to the rotation of a star wheel. The star wheel engages with the tape which runs under a slotted guide roller.

When no tape is passing through the transmitter the bell-cranks perform an alternate up and down movement, making contact with two fixed contacts on an insulated block. When blank tape is passed under the guide roller, the peckers are prevented from rising and the bell-cranks

do not make contact with the fixed contacts. When perforated tape is passed through the instrument, one pecker will pass through each signal hole, and in doing so will permit the contact on the other arm of the bell-crank to rest against its associated fixed contact.

For a *dot* signal the back pecker will pass through a hole in the paper tape and allow its associated contact to make a *fleeting* contact with the fixed right-hand or marking contact. A half-cycle later the back pecker has been withdrawn and a hole in the paper tape brought in line with the front pecker. This will rise and allow its associated contact to make a *fleeting* contact with the left-hand or spacing contact.

Similarly for a *dash* signal a *fleeting* contact is first made by the right-hand contacts just as for a dot signal. The back pecker is now withdrawn, but it is not until three-cycles later that a hole is brought in line with the front or spacing pecker, which is then allowed to rise and with its associated contact to make contact with the left-hand or spacing contact. A long or *dash* signal is therefore transmitted to line, this signal being three times the length of the *dot* signal.

The peckers require no adjustment, being held in accurately turned grooves in the tape star-wheel under the tension of two light springs. Only two adjustments are required, one for the contacts and the other for the height of the tape-feed roller.

The transmitter is motor-driven by means of a variable friction-drive, which consists of a disc mounted on the motor spindle, driving a small rubber-edged disc attached to the transmitter spindle. The motor is fixed in slides in the base to allow friction discs of different diameters to be used for various speeds. The driving disc is held

in contact with the friction disc by the magnetic attraction of the motor field for the armature which is located nearer to one end of the tunnel than to the other, consequently the disc and wheel are only in contact when the motor is actually running.

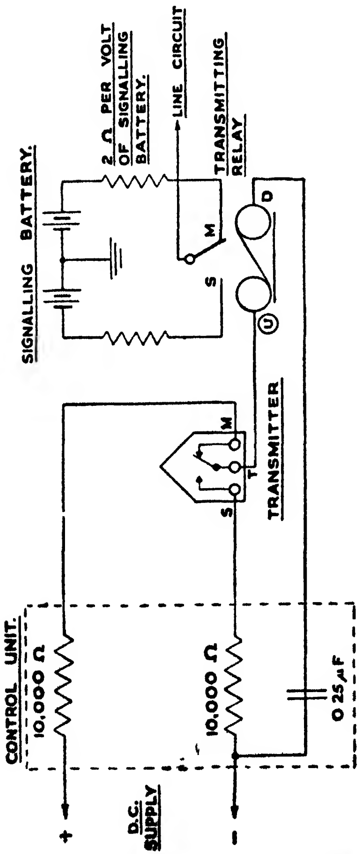


Fig. 116.

Transmission to line is performed by a transmitting relay which is connected in circuit with a special relay control unit as shown in Fig. 116.

When the back pecker rises and allows the moving contact to make fleeting contact with the fixed right-hand contact as already described, the $0{\cdot}25\mu F$ condenser will be charged via the 10,000 ohms resistance and the coils of the transmitting relay. This causes the relay armature to move to its *mark* contact, and so send a marking current to line. At the conclusion of the signal, when the moving contact of the transmitter makes fleeting

contact with the left-hand contact, the $0{\cdot}25\mu F$ condenser discharges through the coils of the transmitting relay and the other 10,000 ohms resistance. This restores the transmitting relay armature to its "space" contact, thus terminating the signal. The relay is adjusted neutrally and the armature will therefore stop in the position in which it was left by the last current received.

Creed Keyboard Perforator.

This instrument is operated by a small electric motor; otherwise it is entirely mechanical. The perforator prepares tape for controlling an automatic transmitter.

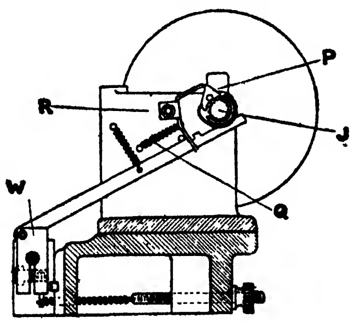


FIG. 117.

The mechanism consists of a keyboard similar to an ordinary typewriter, the keys of which are connected to horizontal key bars operating vertically above twenty combination bars D, and ten space bars, E. These bars are notched on their upper edges according to the requirements of the morse code, and can move transversely below the key bars. Associated with the twenty combination bars are twenty punches with the corresponding die and punch block, I; the space bars, operating through space stops, control a tape feed device having a variable stroke. The punching, feeding and resetting movements are obtained from a three-groove cam, carrying a pawl at one end. The cam is supported on a continuously revolving shaft fitted with a ratchet wheel corresponding

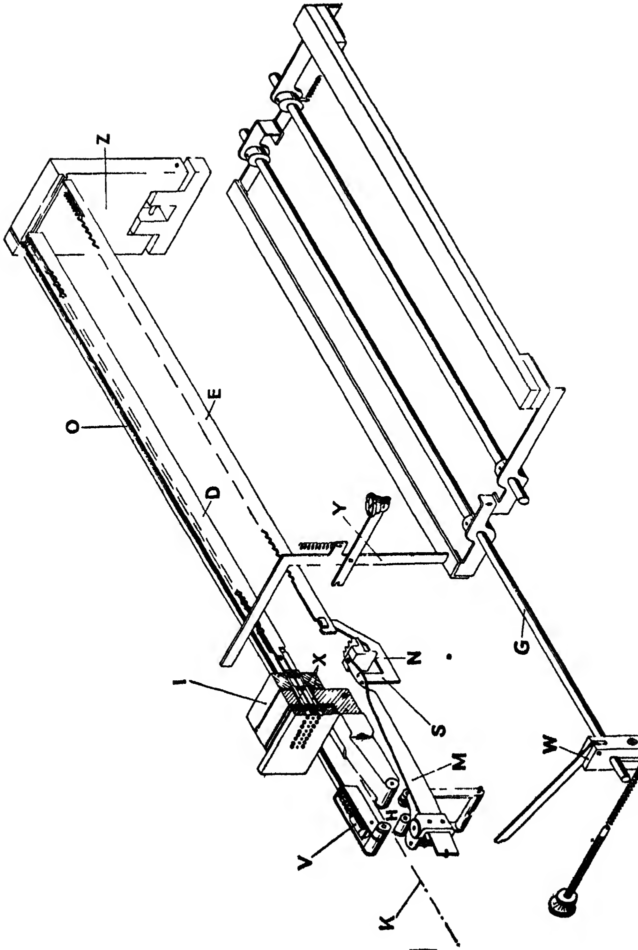


Fig. 118.—Principle of the Creed Morse Perforator.

to the pawl on the cam. On the depression of a key, the cam is brought into operation by means of a trip lever and trigger which control the pawl. Figs. 117 and 118.

The complete cycle of operations is as follows: A key bar *Y* is depressed (Fig. 118). This enters the slots in the comb bars *D* and space bars *E*, and, as it nears the end of its stroke, operates the trip rod *G*, which in turn operates the abutment *R* and allows the pawls *P* to engage with the teeth of the revolving shaft J. The cam then commences to revolve, and first operates the rod *O*, which pushes back the lever *Z* so as to leave space for the comb bars to operate.

As this lever goes back, space bar *E* corresponding to the selected letter will follow it and carry a space stop *S* into the path of the feed rake.

The punch block *I* carrying the punches and the tape is then moved to the right. The punches in this block meet certain bars *D* according to the signal selected, and are forced through the paper tape.

The remaining punches will push the unwanted bars *D* away. The movement of the punch block *I* disengages the feed rake *N* from the paper, and when this has taken place the cam operates the spacing blade *M* and carries the feed rake towards the punch block.

The spacing rake travels down its path until it meets the space stop *S* which determines the length of the tape to be fed. As the cam continues to revolve, the punch block is returned to its normal position, and this causes the paper tape to engage once again with the feed rake *N*, which in turn is moved by the cam to its normal position, thus feeding the paper tape.

Immediately after, the cam operates the lever *Z* and returns the bars *D* and *E* to their normal positions. At

this point the pawls *P* strike the abutment *R* and are thrown out of engagement with the revolving shaft, thus completing the cycle of operations.

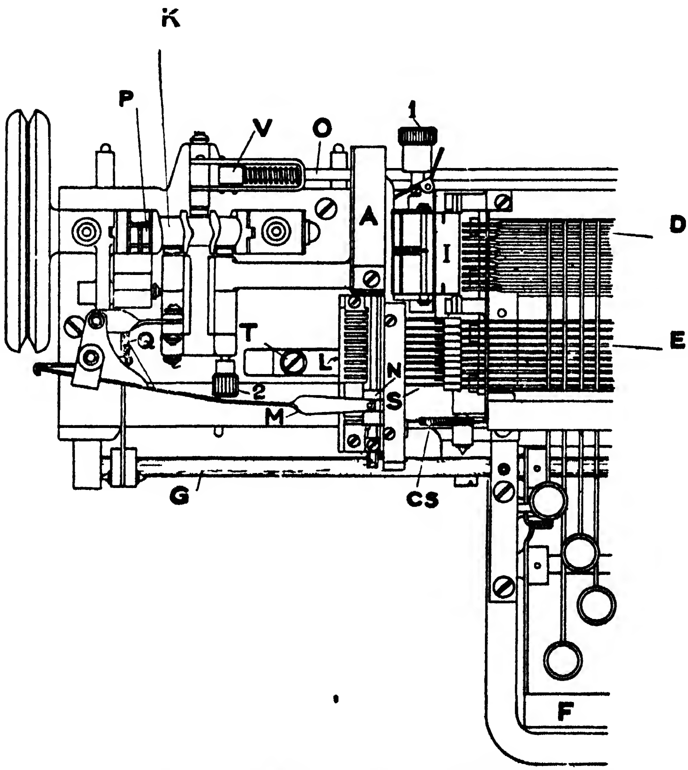


FIG. 119.—PART OF THE MECHANISM OF THE MORSE KEYBOARD PERFORATOR.

The perforator is designed for manual operation, the speed of perforation being dependent upon the typing skill of the operator. Speeds of 80 words per minute can

easily be reached, with a maximum speed of 125 words per minute.

VISUAL LETTER COUNTER. A visual letter counter, special signal key and a warning lamp are provided when it is required to perforate tape that is to be used for automatic transmission to stations employing page morse printers.

The Morse Printer.

The Creed morse printer is an instrument which translates morse signals in a perforated tape into Roman characters, printed upon a paper tape or in page form on a paper roll (see Fig. 120).

This instrument will operate satisfactorily at a speed of 100 words per minute. The page morse printer, Fig. 120, is normally mounted on a pedestal, the associated motor being placed on a shelf immediately below the instrument. With this type of machine, practical experience

FIG. 120.

has shown that it is inadvisable to exceed a speed of 80 words per minute. The printer is controlled by perforations in a paper tape prepared by the receiving reperforator and when this instrument is operating at a speed of 150 words per minute, it is customary to operate two morse printers from the tape prepared on the reperforator; the two morse printers receiving alternate messages perforated. The speed of the printer is controllable between speeds of 50 and 80 words per minute by means of a variable resistor placed at the right of the motor.

THE PAGE PRINTER

The Page Printer is the standard printer for translating morse signals in a perforated tape into Roman characters and printing them upon a *page* 8½ in. wide, fed from a roll and controlled by mechanism contained in a special printing carriage attached to the printer base.

Principles of Operation.

The perforated tape is fed forward through the *selecting head* of the printer letter by letter over a series of ten pairs of selecting needles or *selectors*.

Each selector operates, through a horizontal actuating lever, one of twenty code combination combs, mounted on a drum upon which they are permitted to turn a fraction of an inch against a small spring.

Each comb is slotted with a different arrangement of slots and can be made to occupy one of two positions, one of which in combination with other selected combs, opens an *avenue* in the whole series of combs and permits a spring-controlled latch or bell-crank to drop in.

Passing through the axis of the drum is a spindle which continually rotates the typehead and associated stop through a friction clutch.

When a bell-crank is permitted to drop by virtue of an *avenue* opened in the combs, it arrests the movement of the stop, but the spindle, by reason of the clutch slipping, continues to revolve. Attached to the stop is the typehead. A hammer is timed to strike the back of the particular type brought opposite to it, depending upon the position of the bell-crank which arrested the stop.

The perforated tape is fed forward by a star wheel fitted to a small spindle carrying a toothed wheel, which is rotated by the movement of a cam-controlled rack. This rack is given a forward motion for feeding purposes, but is disengaged from the toothed wheel on its return so that the tape is only fed in one direction. The extent of each forward movement of the rack is limited by the length of a letter, i.e. the distance between the first signal of the letter and the space signal immediately following the last signal of the letter.

To provide for limiting or differentiating in spacing, a set of ten *space-stops* are normally retained in the path of the rack by small springs. The tail of each space-stop rests on a projection on one pair of selectors and the movement of the latter, when either or both selectors pass through a perforation in the tape, causes the head of the corresponding space-stop to be moved out of the path of the rack. With any letter or figure of the International Morse Code there is a clear backward path for the feeding rack until it encounters an unmoved space-stop which corresponds to the space immediately following the last signal hole of the letter.

Hence it follows that the length of the forward

feeding movement is controlled by the distance the rack travelled back to the first unmoved space-stop.

The selectors which correspond to the perforated signal presented by the tape are permitted to pass through the holes and thereby complete their maximum movement and thus operate the actuating levers which set the required combination combs. The remainder of the selectors, being held back against their springs by the paper, are thus prevented from moving the combination combs.

The ten pairs of selectors are moved in a downward direction with every revolution of the camshaft by means of a returning bar, and they are then released and allowed to rise to the paper under the action of small springs, when the tape has been fed, in readiness for the translation of the next signal.

A special signal, originally prepared in the tape by the operation of the *carriage return* key of the keyboard perforator at the transmitting station, is used to operate the carriage control bell-crank. An independent drive is taken from the main camshaft, and through a universal joint, supplies an oscillating movement for the purpose of feeding the carriage the space of one letter per movement. This feeding movement is arranged to wind up a clock spring which, when released through the action of the *carriage return* mechanism, supplies the power to return the carriage for the commencement of a new line. At the same time the carriage control mechanism actuates page feeding mechanism which causes the platen to be revolved a definite amount to provide adequate interspacing of lines of print.

CODE. The Printer is controlled by perforations in a paper tape prepared on a Creed receiving reperforator,

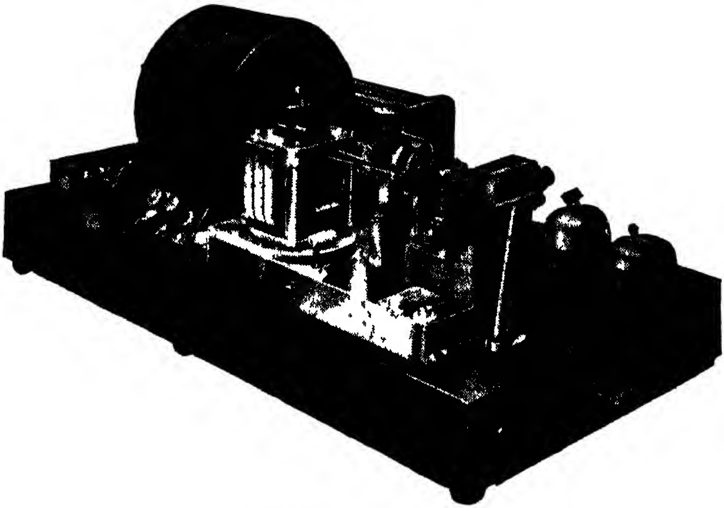


FIG. 121.—THE MORSE RECEIVING REPERFORATOR.

the perforations corresponding to the signals of the International Morse Code. The keyboard perforator at the transmitting station is fitted with a visual letter counter to enable the operator to know when to operate the *carriage return* signal key.

ARRANGEMENT OF TYPES IN TYPEHEAD. The standard arrangement of types is normally used, but modifications can be made according to the layout selected for the keyboard perforator in use at the transmitting station. The various characters, figures and symbols are mounted upon small type-bars carried in a revolving typehead and the selected type is caused to strike the paper page.

PAPER. Paper for page printing is supplied in rolls of 360 ft. approximately. After printing, the messages

can be torn off against a knife-edge provided for the purpose.

THE MOTOR. An $\frac{1}{8}$ h.p. motor drives the main shaft by means of a belt running over pulleys (ratio 1: 1) and, through gears, the typehead spindle and camshaft. A sliding speed-control resistance is provided, together

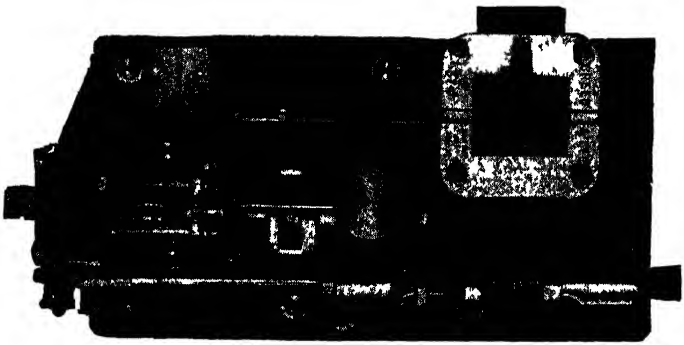


FIG. 122—THE PERFORATING HEAD.

with fuses and a starting switch. The resistance and fuses, together with the motor, are mounted on a wooden shelf located midway between the wooden sub-base of the printer and the tubular stand feet. The switch is mounted adjacent to the printer on the top shelf.

The standard motors are for 110 volts or 220 volts D.C.

CHAPTER X

TELEPRINTER WORKING OVER RADIO LINKS USING MULTI-CHANNEL VOICE FREQUENCY EQUIPMENT

TELEPRINTER transmission and reception can be provided on a multi-channel voice frequency telegraph system connected to a radio link.

With a radio link—or circuit—good enough to provide 97 per cent accuracy of printing the teleprinter is a simpler and speedier method of transmitting a message than by morse keying.

There is no doubt that in the future there will be a distinct tendency to increase the number of teleprinters working over radio links—using channelling equipment for economy—and a corresponding reduction in morse working.

Because of poor signal to noise ratio, general and selective fading, the standard of multi-channel voice frequency telegraph system—known as a single tone system—described in Chapter I is not suitable for use over long H.F. radio links—since its efficient operation is dependent upon a steady level of tone being received; i.e. the receive relay is biased and a critical balance between bias and rectified current is necessary—see pages 29 and 30.

For operation over long H.F. radio links it is therefore usual to employ either "two-tone" or "four-tone" working as these systems compensate for these harmful effects.

Two-Tone Working.

With two-tone working, one audio tone is sent for "mark" and a different one for "space." The advantage is that both "mark" and "space" signals are thus given positive indications and the system is less liable to be upset by noise and interference.

The Six-Channel V.F. Two-Tone Equipment.

The frequencies used for the six-channel two-tone V.F. system are shown below. It will be seen that the first two-tone channel uses the frequencies of 420 cps. marking and 540 cps. spacing, i.e. the first two channels of a standard V.F. system.

The transmitting and receiving band-pass filters, the static relay and the V.F. generators are similar to those used in the standard multi-channel voice frequency system described in Chapter I. To effect two-tone working especial detector units are installed in the receiving equipment. Furthermore, the two static relays are connected in series, with the connections on the even channel reversed.

The effect then is that with marking conditions (negative potential) on the send side of the physical extension. The static relay on marking side of the channel 420 cps. allows tone to pass to the radio channel and thus to the receive relay at the distant end, while tone on the space side of the channel is suppressed. When a space signal —positive potential—is applied to the send side of the channel, 540 cps, allows tone to pass to the distant receive relay while tone on the marking side is suppressed. The other channels function similarly on the frequencies indicated. The two frequencies used for each circuit are detected separately at the receiving terminal and,

via valves with their anode circuits connected in push-pull operate the receiving relay to either mark or space.

The anode voltage of each of the output stages is fed differentially through the windings of the receiving relay common to both detector circuits; the H.T. supply being connected to the centre point of the relay, which will therefore operate in tone "double current" fashion.

Two adjacent frequencies are used for each two-tone channel, e.g. 420 and 540 cps. because, being close together, if fading is experienced the incidence of fading of each frequency is therefore nearly equal. The detrimental effects of fading are therefore much reduced, furthermore as one frequency works in opposition to the other the effect of simultaneous noise on each band tends to cancel out.

Work in connection with the efficient working of teleprinters and teleprinter automatic equipment over radio links using channelling equipment is really still in the development stage.

Research in design of two-tone and four-tone equipment continues with a view to reducing the harmful effects of fading and noise to a minimum and thereby obtain 100 per cent circuit continues.

Two-Tone Channel.	*Spacing.*	*Marking.*
1	540 cps.	420 cps.
2	780 cps.	660 cps.
3	1020 cps.	900 cps.
4	1260 cps.	1140 cps.
5	1500 cps.	1380 cps.
6	1740 cps.	1620 cps.

TELEGRAPH TERMS AND DEFINITIONS

ANSWER BACK UNIT.—The *answer back* unit of a teleprinter enables the sending operator to verify that the distant teleprinter is in readiness for reception and, on teleprinter switching systems and Telex working, to verify that connection has been established with the desired station.

ATTENUATION.—The decrease in magnitude of the transmitted power, voltage or current due to line or apparatus. Quantitatively, the attenuation is expressed in nepers or decibels by comparing the magnitude of the received with that of the sent power, voltage or current.

AUTOMATIC TRANSMITTER.—*See* TRANSMITTER, AUTOMATIC.

AUTOSTOP ARM.—A light lever associated with an automatic transmitter, which, when lifted by the perforated paper slip stops the transmitter by switching off the power.

B

BAND PASS FILTER.—A filter designed to pass a given band of frequencies between lower and upper limits, determined by the values of its coils and condensers.

BAUD.—*See also* TELEGRAPH SPEED. The unit of telegraph speed. It is the time interval occupied by the signal element in telegraphy; variable in number for different letters in the Morse system but constant for systems employing the five-unit code such as teleprinter and Baudot working.

BAUDOT WORKING.—A type of multiplex printing telegraph system using five-unit code. A system discontinued in this country but still employed on the Continent.

BEL.—The Bel is the unit used in the comparison of the magnitude of powers, voltages, or currents at two different points in a network of lines or apparatus.

If two powers are concerned the number of Bels expressing

their relative magnitude is the logarithm to the base 10 of the powers, i.e.:

$$\text{Bels} = \log_{10} \frac{P_s}{P_r} \qquad \text{where } P_s \text{ is power sent; } P_r \text{ ,, received.}$$

If two voltages or currents are concerned the number of Bels expressing their relative magnitude is twice the logarithm to the base 10 of the ratio of the voltages or currents, i.e.:

$$\text{Bels} = 2 \log_{10} \frac{E_s}{E_r} \qquad \text{where } E_s \text{ is voltage sent; } E_r \text{ ,, received.}$$

$$\text{Bels} = 2 \log_{10} \frac{I_s}{I_r} \qquad \text{where } I_s \text{ is current sent; } I_r \text{ ,, received.}$$

The Decibel is $\frac{1}{10}$ of a Bel.

$$\text{Decibel} = 10 \log_{10} \frac{P_s}{P_r} \text{ or } 20 \log_{10} \frac{E_s}{E_r} \text{ or } 20 \log_{10} \frac{I_s}{I_r}$$

BIAS.—A one-sided inclination or leaning.

BIAS DISTORTION.—Distortion due to either the marking or spacing elements of the signals being lengthened due to asymmetry in the transmitting or receiving apparatus.

BIASED RELAY.—A relay having its tongue held on one of its contacts under resting or idle conditions. When operated the tongue moves to the other contact, then returns to the resting contact on cessation of the current. The bias can be achieved by mechanical, magnetic or electrical means.

BRIDGE DUPLEX.—A duplex system in which the neutrality of the receiving apparatus at each end to the currents sent from that end is secured by a balance of potentials on the Wheatstone Bridge principle. The receiving instrument occupies the position of a galvanometer, in a Wheatstone's Bridge, so that the outgoing current does not affect the home instrument although operating the distant receiving instrument.

BROADCASTING.—Broadcasting in telegraphy can best be explained by comparing it with wireless broadcasting. In the case of a telegraph broadcast the transmitting teleprinter station is connected at a switchboard or concentrator, via special relays, to a number of selected stations. All stations so connected receive the message simultaneously.

BROADCAST SWITCHBOARD NO. 14.—A broadcast switchboard normally used for association with forty selected circuits on a telegraph switchboard No. 9. Only these forty selected stations can receive a broadcast message.

BROWN SUBMARINE RELAY.—A submarine cable relay in which a long light pointer attached to the moving coil bears lightly and makes contact with one or other half of a rotating drum. The halves are connected to a positive or negative polarity for local relaying circuit.

C

CADENCE.—A signal for the operator of a Bandot or similar telegraph keyboard to depress signal-group of keys.

CARRIER WAVE TELEGRAPHY.—*See* TELEGRAPH, CARRIER WAVE.

CENTRAL BATTERY.—Central battery implies a system in which the power supply for telegraph signalling is located in a central office.

CHARACTERISTIC DISTORTION.—The distortion occurring consistently with any given series or combination of signal elements. Due mainly to line characteristics, i.e. line capacity, etc.

CHARACTERISTIC IMPEDANCE.—The limiting value towards which the impedance of a transmission line tends as its length is indefinitely increased.

COMBINER UNIT.—Is a piece of apparatus to which a number of stations are connected. It gives facilities for any one station to transmit to individual stations, or to the whole of the stations so connected. All stations can transmit and receive to and from the remainder of the stations forming the combination (see Fig. 68 No. 4).

COMPOSITED CIRCUIT.—A circuit in which are obtained simultaneously either one telegraph and one telephone channel from one line wire and earth, or two telegraph channels and one telephone channel from two physical conductors. Segregation of the channels is obtained by suitable filters or the combination of either (see pages 126 and 127).

CONCENTRATOR.—This is used when either floor space is limited or the traffic passing over the circuits is not heavy. Instead of terminating on the teleprinter or morse apparatus, the lines are terminated on the concentrator jacks. At the terminal station the transmitting and receiving portions of the apparatus are brought out or connected to a cord and plug. Insertion of a plug into the jack on the concentrator gives connection to line: an indicator lamp lights on the concentrator when an out-station is calling.

CONFERENCE UNIT.—*See* COMBINER UNIT.

CONVEYOR BELT.—A belt system driven by motors, used for conveying the telegraph message between the telegraph instrument and the message distribution point.

CORRECTION.—A means by which rotating instruments at the two ends of a synchronous telegraph circuit are kept in place or unison.

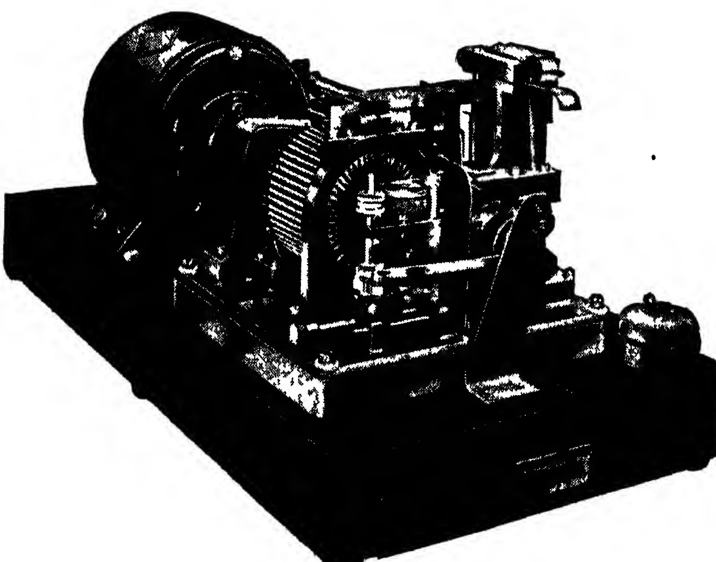


FIG. 123.—THE CREED MORSE PRINTER.

CREED DIRECT PRINTER.—A printing telegraph receiver adapted for actuation directly by the received signals without perforation of a tape.

CREED RECEIVING PERFORATOR.—The instrument in the Creed printing telegraph system which punches the strip at the receiving station.

D

DECIBEL.—*See* BEL.

DEGENERATIVE REPEATER.—*See* REPEATER, DEGENERATIVE.

DISTORTION.—The change in shape of a transmitted wave which occurs between any two points of a transmission system. *See also* MARGIN.

LETTERS	FIGURES	UNITS					LETTERS	FIGURES	UNITS				
		I	II	III	IV	V			I	II	III	IV	V
A	–	●	●				Q	1	●	●	●		●
B	?	●			●	●	R	4		●		●	
C	:		●	●	●		S	'	●		●		
D	WHO ARE YOU	●			●		T	5					●
E	3	●					U	7	●	●	●		
F	%	●		●	●		V	=		●	●	●	●
G	@		●		●	●	W	2	●	●			●
H	£			●		●	X	/	●		●	●	●
I	8		●	●			Y	6	●		●		●
J	BELL	●	●		●		Z	+	●				●
K	(	●	●	●	●		LINE FEED			●			
L	)		●			●	LETTERS		●	●	●	●	●
M	.			●	●	●	CARRIAGE RETURN					●	
N	,			●	●								
O	9				●	●	SPACE				●		
P	0		●	●		●	FIGURES		●	●		●	●

FIG. 124.—THE TELEPRINTER FIVE-UNIT CODE ● MARK SIGNAL.

DISTRIBUTOR.—A rotating device which distributes line connection in quick succession to the different message channels of a multiplex system.

DOUBLE CURRENT WORKING.—This refers to telegraph systems in which signal transmission and reception is effected by means of a combination of positive and negative currents, i.e. by current reversals.

D.T.N.—Abbreviation for *Defence Teleprinter Network.*

DUPLEX BALANCE.—A duplex balance is a network of resistors and capacitances which is adjusted to simulate the distributed resistance and capacitance of the line and apparatus, with which the balance is associated. By its use it is possible to terminate a single wire circuit so that it can be used for simultaneous transmission in both directions.

DUPLEX TELEGRAPH SYSTEM.—A telegraph system in which two messages can be sent, one in each direction, simultaneously over the same line.

F

FACSIMILE TELEGRAPHY.—*See* TELEGRAPHY FACSIMILE.

FILTER.—A network consisting of inductance coils and condensers, so designed that they will offer little or no impedance to electric currents within a given frequency range and a very high impedance to currents outside this range.

FIVE-UNIT CODE.—A telegraph code associated with machine telegraph transmission, in which every character is allocated an individual sequence of five elemental marking and spacing signals.

FORTUITOUS DISTORTION.—Distortion due to irregularities in any part of the circuit. Usually caused by external influences, such as adjacent power lines, etc.

FOUR-CHANNEL V.F. TELEGRAPH SYSTEMS.—A V.F. telegraph system in which four two-way channels can be obtained over a two-wire telephone circuit. The frequencies used for transmission in one direction are 420, 660, 900 and 1,140 c.p.s., and in the reverse direction 1,380, 1,620, 1,860, and 2,100 c.p.s. This system is usually installed when provision of

twelve- or eighteen-channel V.F. systems would not be considered economical. For full description see pages 9 to 13.

FOUR-TONE WORKING.—A method of teleprinter transmission over a long radio link. Usually only resorted to when transmission conditions are bad.

FREE LINE SIGNALLING. An arrangement installed on large multiple type teleprinter switchboards to indicate, by means of a lamp above the line jack, the first free circuit in each group.

G

GULSTAD RELAY.—A sensitive form of telegraph relay in which the tongue is normally kept vibrating by an auxiliary winding at a speed equal to that of the reve sals of current at the distant transmitter, so that the line currents only have to act in arresting the vibration of the tongue temporarily and holding it over against one stop.

H

HELL PRINTER SYSTEM.—A wireless telegraph system invented by the German engineer Hell and developed by the Siemens Halske Company. The Hell printer system combines the principles of picture telegraphy and printing telegraphy. See pages 149 to 159.

HIGH PASS FILTER.—A filter which prevents the passage of alternating currents below a certain frequency, but offers little or no impedance to those above that frequency.

I

INLAND TELEGRAPHY.—Inland telegraph is the transmission of a message by one of the various telegraph systems over landlines laid within territorial limits.

IN-STATION BAY (V.F.).—The in-station equipment of a four-channel V.F. system. It is mounted on a 10 ft. 6 in. rack and lines-up with the eighteen-channel equipment. The detector panels and relays are identical with those used on main line systems and the filament, anode and telegraph

supplies are obtained from the main station 24 V., 130 and ± 80 V. supplies (other telegraph voltages may be used). The carrier supplies are obtained from one of the multi-frequency generators which supply the main line equipment.

INTERMEDIATE DISTRIBUTION FRAMF I.D.F. (*Purpose of*).—An angled iron framework carrying termination blocks, installed between the telegraph apparatus and the main distribution of telephone, telegram and phonogram circuits to adjust the loads on the different suites. It also provides a means of interconnecting the various items of telegraph equipment, such as teleprinters, switchboards, power equipment, morse equipment, and V.F. channels.

L

LINE TELECOMMUNICATION (L/T).—Communication using the same technique as that used in connection with landlines and submarine cables.

LOCAL RECORD.—A reproduction by the transmitting telegraph instrument of the message transmitted. (See page 60.)

M

MAIN DISTRIBUTION FRAME (M.D.F.) (*Purpose of*).—An angled iron framework carrying terminal blocks which provides the following facilities:

(*a*) A means of terminating the external cables.
(*b*) A means of inserting protective devices in the circuits (fuses, heat coils and protectors).
(*c*) Rearranging the circuits from their cable order to the desired numerical order by jumpering across the frame.

MARGIN.—The maximum amount of signal distortion which may be permitted before the receiving mechanism of a telegraph instrument fails to operate. ***Distortion*** or ***margin*** is the amount early, or late, with respect to its correct position with regard to the start signal, of any current change-over, expressed as a percentage of the unit signal element.

MARGIN "EXCESS."—The amount by which the margin exceeds the maximum effective signal distortion which occurs during transmission. It is a means of measuring the transmission efficiency of the system.

MARKING SIGNAL (*Standard defini ion*).—The telegraph signal which causes the paper of the distant end to be marked.

With modern practice this is not strictly true, since each character printed is the result of a combination of marking and spacing signals. With teleprinter working, however, it is the *marking* signal which causes the striker blade to hit, and displace the comb-setting fingers, whereas a space signal does not. The start signal is a spacing signal, the stop signal is a marking signal.

MORSE CODE.—A telegraph code in which characters are formed from combinations of two signals of unequal duration known as the dot and dash. The dot is the elementary signal unit, the length of the dash being three times that of the dot. These signals are spaced by an interval equal to the period of one unit, and consecutive letters of any word are spaced by an interval equal to three units. A space between words has a duration of five units. Dots and dashes are signalled at one potential and the intervening spaces at another potential. A limit to the number of combinations available is set only by the practical need to keep characters as short as possible.

MULTIPLE WAY SYSTEM.—A telegraph system in which two or more messages are sent over the same wire simultaneously, either (1) where each has whole-time connection to the line, or (2) by allocation of the exclusive use of the line to each way in rapid succession.

MULTIPLEX TELEGRAPHY.—Multiplex telegraphy refers to those systems in which signals are transmitted by means of segmented distributors, working in synchronism at both ends of a circuit. Successive segments on the distributor can be constructed to enable two to six operators to be given consecutively the exclusive use of the line during the period of rotation of the distributor. By this means several messages

can be transmitted over a single circuit at the same time. Duplex working can also be arranged so that a maximum of twelve simultaneous message transmissions over a single circuit can be obtained.

Examples of this system are Baudot, Murray, Western Electric and Western Union.

N

NEPER—A unit used in the comparison of the magnitudes of powers, voltages or currents at two different points in the network of lines or apparatus. See also BEL. 1 Neper = 0·8686 Bel.

OMNIBUS TELEGRAPH SYSTEM.—A system in which a number of stations are permanently interconnected, the signals transmitted by any one station being received by all.

OUT-STATION.—This term usually refers to a small telegraph office remotely situated from the main telegraph office.

OUT-STATION BAY (V.F.).—The out-station equipment of a four-channel V.F. system. It is mounted on both sides of an 8 ft. 6 in. rack and includes rectifying equipment (incorporating copper-oxide rectifiers) to obtain the necessary supplies from A.C. mains. Three rectifier panels are provided per channel; one supplies the filament and anode circuits, the second supplies ± 80 volts to the transmitting of the telegraph instrument and the third supplies ± 80 volts to the contacts of the receiving relay. Carrier supplies are obtained from four single-valve oscillators and the detectors and relays are of normal type. The main supply to each channel is separately fused and may be switched off independently of other channels. A master switch and fuse is also provided.

OUT-STATION EQUIPMENT.—The telegraph equipment installed at the out-station.

OUT-STATION Frequencies (*Multi-Channel V.F. Working*). —The carrier frequencies generated by the out-station

multi-channel V.F. equipment. These frequencies are 1,380, 1,620, 1,860 and 2,100 c.p.s. for a four-channel system and 2,100, 1,860, 1,620, 1,380, 1,140, 900, 660 and 420 c.p.s. for an eight-channel system, the frequencies being produced by valve and oscillators.

P

PATCHING JACKFIELD (*Teleprinter*).—A jackfield installed in large teleprinter offices to introduce a measure of flexibility. The incoming telegraph circuits pass through the patching jackfield to the teleprinter positions. Thus, by the insertion of a double-ended cord, any telegraph circuit can be connected to any teleprinter position desired.

PERFORATOR.—An instrument used for perforating a paper slip in accordance with the morse or five-unit code. In its modern form its keyboard is very similar to that of a typewriter. The depression of any key results in the operation of a number of punches which perforate the paper slip. (See Figs. 84, and pages 117 to 119.

PHONIC WHEEL.—A toothed wheel driven electromagnetically from a vibrating reed or fork.

PHONOGRAM.—A phonogram is a telegram which is telephoned by a telephone subscriber, or a caller at a public call office, to a telegraph office, or conversely from a telegraph office to a telephone subscriber.

POLAR RELAY.—American term for polarised relay.

PRINTAGRAM (PRM).—A printagram is a telegram transmitted by a Telex subscriber to a P.O. printagram centre or, conversely, from a printagram centre to a Telex subscriber. The PRM service is essentially similar to the phonogram service for telephone subscribers in that connection between the Telex subscribers and PRM's is first established on a telephone basis, the transmission of the telegraphic message then being effected by a teleprinter transmission on a voice frequency signalling basis. Circuit arrangements are such that a printed local record of the message together with an acknowledgment is obtained.

PRINTING TELEGRAPHY.—Any method of telegraph operation in which the received signals are automatically recorded in printed character.

Q

QUADRUPLEX SYSTEM.—A morse code telegraph duplex system in which the circuit is arranged for the simultaneous transmission of two messages in each direction over a single circuit. The one channel responding to a *reversal* of current, the other actuated by the *amount* of current flowing.

R

RADIO TELETYPE (RTT).—The name given to the American system of working Teletypewriters over a radio link.

RECEIVING RELAY.—The telegraph relay inserted at the receiving end of a circuit. In the voice frequency telegraph system a receive relay is inserted in each receive channel. It is a biased relay operated by the incoming rectified signals, see page 30.

REGENERATIVE REPEATER.—A regenerative repeater is a telegraph repeater which accepts distorted signals and retransmits them as reshaped signals essentially free from distortion.

The action of the regenerative repeater in reshaping the received signals enables long cable circuits to be extended via landlines and also permits a higher signalling speed.

RELAY.—An electrically operated device for opening and closing circuits.

RELAY NEUTRAL.—A polarised relay so arranged that it operates in one direction or another from a normal neutral position according to the direction of the current in the controlling circuit.

RELAY, NON-POLARISED.—A relay, the operation of which depends upon the magnitude of the current flowing in the controlling circuit irrespective of the direction of the current. Originally used in Quadruplex working.

RELAY POLARISED.—A relay, the operation of which depends

primarily upon the direction of the current in the controlling circuit.

REPERFORATOR.—An electro-mechanical instrument for perforating a paper slip in accordance with the morse or five-unit code. It is actuated by the incoming electrical impulses on the telegraph circuit with which the instrument is associated.

REPEATER.—A device whereby currents received over one circuit are automatically repeated in another circuit or circuits, generally in an amplified form.

REPEATER (*Degenerative*).—A repeater associated with a point to point teleprinter circuit for security reasons, its functions being to distort the transmitted signals. At the distant end the distorted signals pass through a special form of regenerative repeater before operating the receiving teleprinter.

REPEATER REGENERATIVE (*See* REGENERATIVE REPEATER).

S

SEND FILTERS.—The name given to the filter inserted at the transmitting end of a voice frequency telegraph channel.

SEND RELAY (V.F.).—*See* STATIC RELAY.

SIDE CIRCUIT.—A two-wire circuit forming one side of a phantom or superimposed circuit.

SIMPLEX TELEGRAPH WORKING.—Simplex telegraph working refers to those systems in which, at any instant, the transmission of signals in a circuit must be confined to one direction only.

SINGLE CURRENT SYSTEM.—Single current telegraph working refers to systems in which the transmission and reception of signals is effected by means of unidirectional currents.

SONIC TELEGRAPHY (S/T).—Sonic telegraphy is the communication of a message by sound waves through water and is used principally by submarines.

SOUNDER.—A telegraph receiving instrument in which morse signals are translated into sound signals determined by intervals between two diverse sounds.

STAR QUAD CABLE.—A cable containing a number of quads,

each quad formed by twisting together four insulated conductors about a common axis.

START-STOP TELEGRAPHY.—*Start-Stop Telegraphy* is a system of telegraphy which avoids the necessity of maintaining absolute synchronism between the transmitting and receiving apparatus. This is arranged by starting and stopping the transmitting and receiving mechanism at the beginning and end respectively of each character combination transmitted. Thus the two machines are in phase at the beginning of each combination transmitted, and any difference in speed between the transmitting and receiving mechanism is not cumulative. The transmitter and receiver speeds are controlled within close limits by means of a governor, so that the maximum phase displacement between the transmitting and receiving mechanism during any signal is small.

The Creed teleprinter is an example of the *Start-Stop* class of telegraph apparatus.

STATIC RELAY.—The relay inserted in every send channel of a voice frequency telegraph system.

The telegraph signal operates the send relay which modulates the V.F. carrier wave. See pages 16 to 18.

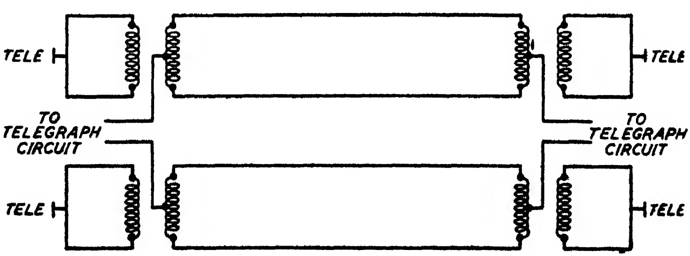


FIG. 125.—A SUPERPOSED TELEGRAPH CIRCUIT.

SUPERPOSED CIRCUIT.—An additional circuit obtained from a two-wire circuit or circuits in such a manner that the service over the additional circuit can be given simultaneously with the services over the other circuits and without interference with the latter. The telegraph circuit is superposed.

SYNCHRONISM.—The term *synchronism* as applied to distributors in multiplex telegraphy means that the distributors at each end of the telegraph circuit are running at identically the same speed and with correct phase.

SWITCHBOARD (*Telegraph*).—The means provided for the inter-connection of the telegraph circuits terminating thereon. It also provides a means whereby any station connected to the switchboard can broadcast to a selected number of stations (connected to the switchboard) simultaneously.

T

TELEGRAPH (*Carrier Current or Carrier Wave*).—A system of telegraphic signalling using carrier waves over an electrical circuit. The carrier waves may be audio (as in the Voice Frequency System) or ultra-audio frequency.

TELEGRAPH CROSSTALK.—The interference in one telegraph channel resulting from another channel.

TELEGRAPH (*Facsimile or Picture*).—A system for the transmission of still pictures, or printed matter, over an electrical circuit.

TELEGRAPH LANE.—An American expression, used when referring to traffic over a number of channels in the same system, e.g. the pattern of the Inland Telegraph network, if it could be photographed, would appear something like a spider's web. The Central Telegraph office can be pictured as the centre of the web and telegraph traffic lanes the supporting silken threads which radiate in each direction from the centre.

TELEGRAPH PRIVATE WIRES, TARIFFS.

TARIFF A.—Private teleprinter simplex service using teleprinters No. 7. This service may be on:

(1) By-product circuits on .telephone trunks with a maximum line current of 10 mA.

A maximum line voltage of $\pm$ 20 V. and

A maximum local line voltage of $\pm$ 40 V., or

(2) A channel in V.F. Telegraph network. In this case the local line volts are $\pm$ 40 or $\pm$ 80 V. with D.C. working

on the A wire from the renter's office with a $\pm$ 40 or $\pm$ 80 V. battery.

TARIFF B.—Private low-speed telegraph service. Duplex operation is used, the apparatus being provided by the renter. Any two elements system may be used and the maximum speed is not less than 80 bauds.

The circuit may be:

(1) By-product.

(2) V.F. telegraph channel, or

(3) A telephone pair.

TARIFF C.—Private high-speed telegraph service. Duplex operation is used, the apparatus being provided by the renter. Any two elements system may be used and the maximum speed is not less than 160 bauds. The circuit may be a high-speed V.F. channel or a telegraph circuit.

TARIFF D.—Private telephone service with alternative teleprinter facilities. The telegraph apparatus is the same as for Telex service.

TARIFF E.—Private high-grade facsimile or music transmission. Apparatus is provided by the renter. The facility requires a high-grade trunk circuit.

TARIFF Y.—Private wire circuits are occasionally made up of a telephone and a telegraph circuit in tandem. Telex equipment being fitted at the telephone circuit and the Tariff A or other type of D.C. telegraph equipment at the other end. At the junction of the two circuits a Tariff Y converter converts D.C. to V.F. transmission and vice-versa. Tariff Y converters have not been standardised, since they have been designed to meet particular requirements. In general, their performance is similar to that of Converters, V.F. Telegraph Nos. 9 and 10 used for Telex.

TELEGRAPH SPEED.—Telegraph speed may be measured either in characters or words per minute, or in bauds. A word is accepted as consisting of five letters and a space, or six characters.

BAUD.—The unit of telegraph speed. Telegraph signals

are characterised by intervals of time or duration equal to, or greater than, the shortest or elementary intervals. Telegraphic speed is therefore expressed as the inverse of the value of the elementary interval in seconds. A speed of one elementary interval per second is termed one baud. For example, in the teleprinter code each character consists of five units plus one start unit and one and a half stop units, a total of $7\frac{1}{2}$ units. Thus each revolution of the cam sleeve represents a transmission of $7\frac{1}{2}$ units.

$$\text{Hence Transmission speed} = \frac{7\frac{1}{2}\text{ units}}{t\text{ seconds}}\text{ Bauds.}$$

where t = time in seconds taken for one revolution of the cam sleeve.

In the Teleprinter 7A the speed of the transmitting cam sleeve is 400 revolutions per minute. One revolution thus takes

$$\frac{60}{400}\text{ sec.} = 0{\cdot}15\text{ sec.}$$

Therefore Transmission Speed of Teleprinter 7A

$$= \frac{7{\cdot}5\text{ units}}{0{\cdot}15\text{ sec.}}$$

$$= 50\text{ Bauds.}$$

TELEPRINTER SIGNALLING SPEED (C.P.S.).—The maximum possible number of cycles (from positive to negative, or marking and spacing) obtainable with one revolution of the cam sleeve is half the total number of units, i.e. $3\frac{3}{4}$.

Thus the transmission speed in cycles per second

$$= \frac{3\frac{3}{4}}{t\text{ secs.}}$$

$$= \frac{3{\cdot}75}{0{\cdot}15}$$

$$= 25\textit{ cycles per second.}$$

TELEPHONE TELEGRAM.—A telephone telegram is a telegram which is transmitted by a telephone between two Post Offices and the method employed for this purpose is known as telephone-telegram working.

Teleprinter (Teletypewriter U.S.A.).—A self-contained telegraph instrument fitted with a type keyboard for transmission, and a printing mechanism for reception.

Teleprinter Start Stop Signal.—During idle periods on a teleprinter circuit the receiving mechanism is at rest and the purpose of the start signal is to set it in motion immediately before the reception of the five-unit code signals. The function of the stop signal which follows the five-unit signals is to bring the receiving mechanism to rest before a further start signal is received. By starting and stopping the receiving mechanism in this manner the distortion resulting from non-synchronism between the sending and receiving teleprinters is limited to that occurring during the time of transmission of a single character, i.e. during approximately 1/7th sec., and a relatively simple form of governor can, therefore, be used on the teleprinter motor.

The start signal is equal, or approximately equal in length to a unit signal and is of spacing polarity. The stop signal may be of length equal to one or one and-a-half times the length of a unit signal and is of marking polarity.

Teleprinter Auto-start Switch.—The auto-start switch, as fitted to the teleprinter, enables the power supply to the motor to be automatically switched on when the first start element of a teleprinter message is received and to be switched off again some ninety seconds after the receipt of the last marking element. As a local record of transmitted messages is often provided with teleprinters, it follows that the motor is also automatically stopped some ninety seconds after the end of a transmission. The switch, therefore, ensures that

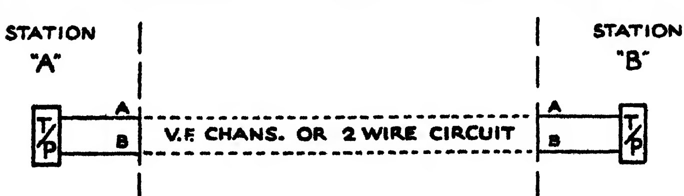


Fig. 126.—A Point to Point Teleprinter (t/p) Circuit.

the motor is running only during the transmission and reception of messages.

TELEPRINTER (*Summary of operational details*).—

3A (*Tape*)

Code	7½ units Sending and Receiving.
Speed	49 Bauds. 65 words per min.
Operating Voltages	40 or 80
Operating Current	17 mA.
Maximum Operating Margin	35% Early. 30% Late.

7A (*Page*)

Code	7½ units Sending and Receiving.
Speed	50 Bauds. 67 words per minute.
Operating Voltage	40 or 80.
Operating Current	15 mA.
Maximum Operating Margin	35% Early.
Margin	35% Late.

7B (*Page*)

Code	7½ units Sending. 7 units Receiving.
Speed	50 Bauds. 67 words per minute.
Operating Voltages	40 or 80.
Operating Current	15 mA.
Max. Operating Margin	35% Early. 38% Late.

TELEX SERVICE.

Telex Service affords facilities for intercommunication between teleprinters via the normal telephone exchange switching network. A telex subscriber's equipment consists of a page type teleprinter and associated V.F. signalling unit, also a telephone instrument and changeover switch by which either the telephone or teleprinter equipment may be asso-

ciated with the subscriber's telephone exchange line. A telex connection is set up by using the telephone in the normal manner, but having established connection with the required subscriber teleprinter messages may then be interchanged by operating the telex switch to the *teleprinter* position and then transmitting from the teleprinter. Circuit arrangements permit simplex transmission with local record and interruption facilities· also a means for automatically checking the accuracy of a connection is given by the subscriber's answer back unit.

TRANSMISSION SPEED.—(*See* TELEGRAPH SPEED).

TRANSMISSION LEVEL.—A measure of the ratio of the power at any point in a transmission line to the transmitted power to a standard reference power. Transmission levels are expressed in decibels or nepers, *q.v.*

TRANSMITTER AUTOMATIC.—A transmitter of the teletype, Wheatstone or Creed type designed to transmit signals automatically at a steady high speed. It is used in conjunction with a paper slip, which has been perforated in accordance with the morse or five-unit code.

TWO LINE SIMPLEX.—Two line simplex is a method of signalling between two offices in which each of the two lines provided is used as a separate earth return circuit for transmission in one direction only. Thus messages can be transmitted in both directions simultaneously without the need for the careful adjustments of the balancing equipment associated with duplex working.

TWO-TONE WORKING.—The system usually adopted when teleprinters are operated over long-distance radio links. With two-tone working one audio tone is sent for a "mark" signal and a different one for "space." The object is to overcome the harmful effects of noise and fading prevalent on radio links.

V

VARIOPLEX WORKING.—A time division multiplex system. The varioplex method of telegraphic operation provides

each pair of stations connected together by it an ever-ready two-way channel for the exchange of traffic, which occupies a band width of zero when idle and of variable width when busy, depending upon the extent of simultaneous usage by other connected stations. See pages 131 to 148.

W

WIRELESS TELEGRAPHY (W/T).—The communication of a message by electromagnetic waves using the morse code.

WHEATSTONE AUTOMATIC SYSTEM.—A high-speed double-current morse system in which the signals are transmitted mechanically and recorded automatically.

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2933	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7

Hyperbolic Logarithms = Common Logarithms × 2·30258.

LOGARITHMS

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	3	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	7982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

Common Logarithms = Hyperbolic Logarithms × 0·43429.

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
·00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
·01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	1	2	2	2
·02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	1	2	2	2
·03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	1	2	2	2
·04	1095	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	2	2	2	2
·05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	2	2	2	2
·06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	2	2	2	2
·07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	2	2	2	2
·08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	2	2	2	3
·09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	2	2	2	3
·10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	2	2	2	3
·11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	2	2	2	3
·12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2	2	2	2	3
·13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2	2	2	3	3
·14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2	2	2	3	3
·15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2	2	2	3	3
·16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2	2	2	3	3
·17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2	2	2	3	3
·18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2	2	2	3	3
·19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2	2	3	3	3
·20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2	2	3	3	3
·21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2	2	3	3	3
·22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	2	2	3	3	3
·23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	2	2	2	3	3	4
·24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	2	2	2	3	3	4
·25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	2	2	2	3	3	4
·26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2	3	3	3	4
·27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	2	2	3	3	3	4
·28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	2	2	3	3	4	4
·29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	2	2	3	3	4	4
·30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	2	2	3	3	4	4
·31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	2	2	3	3	4	4
·32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	2	3	3	4	4
·33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	2	2	3	3	4	4
·34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3	3	4	4	5
·35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3	3	4	4	5
·36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3	3	4	4	5
·37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3	3	4	4	5
·38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3	3	4	4	5
·39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3	3	4	5	5
·40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3	4	4	5	5
·41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	3	4	4	5	5
·42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3	4	4	5	6
·43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3	4	4	5	6
·44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3	4	4	5	6
·45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3	4	5	5	6
·46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3	4	5	5	6
·47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3	4	5	5	6
·48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4	4	5	6	6
·49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	4	4	5	6	6

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
·50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7
·51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
·52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
·53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
·54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
·55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	7
·56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
·57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
·58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4	5	6	7	8
·59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5	5	6	7	8
·60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5	6	6	7	8
·61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
·62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5	6	7	8	9
·63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
·64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
·65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
·66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
·67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
·68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
·69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6	7	8	9	10
·70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6	7	8	9	11
·71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
·72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
·73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	8	9	10	11
·74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6	8	9	10	12
·75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	10	12
·76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
·77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
·78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7	8	10	11	13
·79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	11	13
·80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
·81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8	9	11	12	14
·82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
·83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	9	11	13	14
·84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
·85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15
·86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	13	15
·87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	4	5	7	9	10	12	14	16
·88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
·89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
·90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
·91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
·92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	15	17
·93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
·94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
·95	8913	8933	8954	8974	8995	9016	9034	9057	9078	9099	2	4	6	8	10	12	15	17	19
·96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
·97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
·98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11	13	16	18	20
·99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20

TRIGONOMETRIC FUNCTIONS

ANGLE.		Chord.	Sine.	Tangent.	Co-Tangent.	Cosine.			
Deg.	Radians.								
0°	0	0	0	0	Infinite.	1	1·414	1·5708	90°
1	0·0175	0·017	0·0175	0·0175	57·2900	0·9998	1·402	1·5533	89
2	0·0349	0·035	0·0349	0·0349	28·6363	0·9994	1·389	1·5359	88
3	0·0524	0·052	0·0523	0·0524	19·0811	0·9986	1·377	1·5184	87
4	0·0698	0·070	0·0698	0·0699	14·3007	0·9976	1·364	1·5010	86
5	0·0873	0·087	0·0872	0·0875	11·4301	0·9962	1·351	1·4835	85
6	0·1047	0·105	0·1045	0·1051	9·5144	0·9945	1·338	1·4661	84
7	0·1222	0·122	0·1219	0·1228	8·1443	0·9925	1·325	1·4486	83
8	0·1396	0·140	0·1392	0·1405	7·1154	0·9903	1·312	1·4312	82
9	0·1571	0·157	0·1564	0·1584	6·3138	0·9877	1·299	1·4137	81
10	0·1745	0·174	0·1736	0·1763	5·6713	0·9848	1·286	1·3963	80
11	0·1920	0·192	0·1908	0·1944	5·1446	0·9816	1·272	1·3788	79
12	0·2094	0·209	0·2079	0·2126	4·7046	0·9781	1·259	1·3614	78
13	0·2269	0·226	0·2250	0·2309	4·3315	0·9744	1·245	1·3439	77
14	0·2443	0·244	0·2419	0·2493	4·0108	0·9703	1·231	1·3265	76
15	0·2618	0·261	0·2588	0·2679	3·7321	0·9659	1·218	1·3090	75
16	0·2793	0·278	0·2756	0·2867	3·4874	0·9613	1·204	1·2915	74
17	0·2967	0·296	0·2924	0·3057	3·2709	0·9563	1·190	1·2741	73
18	0·3142	0·313	0·3090	0·3249	3·0777	0·9511	1·176	1·2566	72
19	0·3316	0·330	0·3256	0·3443	2·9042	0·9455	1·161	1·2392	71
20	0·3491	0·347	0·3420	0·3640	2·7475	0·9397	1·147	1·2217	70

21	0·3665	0·364	0·3584	0·3839	2·6051	0·9336	1·133	1·2043	69
22	0·3840	0·382	0·3746	0·4040	2·4751	0·9272	1·118	1·1868	68
23	0·4014	0·399	0·3907	0·4245	2·3559	0·9205	1·104	1·1694	67
24	0·4189	0·416	0·4067	0·4452	2·2460	0·9135	1·089	1·1519	66
25	0·4363	0·433	0·4226	0·4663	2·1445	0·9063	1·075	1·1345	65
26	0·4538	0·450	0·4384	0·4877	2·0503	0·8988	1·060	1·1170	64
27	0·4712	0·467	0·4540	0·5095	1·9626	0·8910	1·045	1·0996	63
28	0·4887	0·484	0·4695	0·5317	1·8807	0·8829	1·030	1·0821	62
29	0·5061	0·501	0·4848	0·5543	1·8040	0·8746	1·015	1·0647	61
30	0·5236	0·518	0·5000	0·5774	1·7321	0·8660	1·000	1·0472	60
31	0·5411	0·534	0·5150	0·6009	1·6643	0·8572	0·985	1·0297	59
32	0·5585	0·551	0·5299	0·6249	1·6003	0·8480	0·970	1·0123	58
33	0·5760	0·568	0·5446	0·6494	1·5399	0·8387	0·954	0·9948	57
34	0·5934	0·585	0·5592	0·6745	1·4826	0·8290	0·939	0·9774	56
35	0·6109	0·601	0·5736	0·7002	1·4281	0·8192	0·923	0·9599	55
36	0·6283	0·618	0·5878	0·7265	1·3764	0·8090	0·908	0·9425	54
37	0·6458	0·635	0·6018	0·7536	1·3270	0·7986	0·892	0·9250	53
38	0·6632	0·651	0·6157	0·7813	1·2799	0·7880	0·877	0·9076	52
39	0·6807	0·668	0·6293	0·8098	1·2349	0·7771	0·861	0·8901	51
40	0·6981	0·684	0·6428	0·8391	1·1918	0·7660	0·845	0·8727	50
41	0·7156	0·700	0·6561	0·8693	1·1504	0·7547	0·829	0·8552	49
42	0·7330	0·717	0·6691	0·9004	1·1106	0·7431	0·813	0·8378	48
43	0·7505	0·733	0·6820	0·9325	1·0724	0·7313	0·797	0·8203	47
44	0·7679	0·749	0·6947	0·9675	1·0355	0·7193	0·781	0·8029	46
45°	0·7854	0·765	0·7071	1·0000	1·0000	0·7071	0·765	0·7854	45°
			Cosine.	Co-Tangent.	Tangent.	Sine.	Chord.	Radians.	Deg.
								ANGLE.	

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